KENAN FELLOWS PROGRAM
FOR TEACHER LEADERSHIP

ISSN 2474-7432

NC STATE
UNIVERSITY

Journal of Interdisciplinary

Teacher Leadership

VOLUME 4, NO. 1 2019

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Journal of Interdisciplinary Teacher Leadership

ISSN 2474-7432

2019, Vol. 4, No. 1

A New Paradigm for STEM Learning and Identity in English Language Learners: Science Translation as Interdisciplinary, Multi-Modal Inquiry

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ABSTRACT

This two-year case study examined multi-modal, interdisciplinary approaches to engage both immigrant English Second Language (ESL) and English Language Learners (ELL) in STEM (science, technology, engineering, math) learning and to build STEM identity and self-efficacy. Leveraging innate abilities, multiple intelligences, and self-identified interests, children in Grades 3 through 8, new to America and STEM, became inquiry-based researchers of sound-making, soundscapes, and nonverbal communication systems in diverse species including human music-making using technology, analysis, communication research, and observation skills. Using generative and lateral thinking methodology for science translation, interdisciplinary methods, and team-based learning, the students demonstrated increased STEM interest, STEM learning, and STEM skill sets while developing self-efficacy as STEM learners and communicators.

Key Words: *science education, immigrant, English Language Learners (ELL), multi-modal learning, interdisciplinary, learner-centered, knowledge translation.*

Background

It is widely observed that despite many efforts by researchers, new policies and programs, educational equity for underrepresented ethnic minority students (URMs) in the United States is an elusive and mostly failed effort (Chemers et al, 2011, p. 442). It is further acknowledged that "Science education has largely been unsuccessful in reaching ELL (English Language Learner), Latino, Native American, African American and other non-mainstream student groups, who remain underrepresented in the field of science" (Meyer & Crawford, 2011). Immigrant children represent nine percent of all U.S. public school students, 4.6 million of which are ELLs whose numbers are growing (DOE, 2015). These students face substantive barriers to full participation in science, technology, engineering, math (STEM) education, often living in intensely segregated, low-income communities with under-resourced schools, and centered in families where parents may have little formal education or familiarity with US educational systems and career pathways (Crosnoe & Turley, 2011).

A growing body of research in the social sciences, psychology, and education suggests ways to counter these forces and to build inclusive pipelines for STEM participation in diverse populations. Common to these findings is the importance of 1) supporting these children's identity and belonging, which is developed through being recognized by oneself and others as capable, valuable, and competent in a given field (Carlone, Scott, & Lowder, 2014; Luehmann, 2007; Buxton & Provenzo, 2010), and 2) reevaluating learning environments and methods (Robinson & Aronica, 2015; Meyer & Crawford, 2011) in support of creating an authentic immigrant context for STEM knowledge construction and communication. Developing a productive STEM learner identity involves providing opportunities to develop and deepen STEM content understanding and practices, to contribute to a community of learners, and to develop a sense of self-efficacy as a STEM learner (Calabrese Barton & Tan, 2010; Herrenkohl & Mertl, 2010). Research in the learning sciences also stresses the importance of engaging student interest and participation through leveraging personal interests and histories (National Research Council, 2015). To broaden participation in STEM learning, it is essential that programs position students' interests, histories, and skills as assets, or "funds of knowledge" (Moje et al., 2004; Moll, Amanti, Neff, & Gonzalez, 2009) – building blocks central to the purpose and activity of the program (Eisenhart, Finkel, & Marion, 1996; Lemke, 2001).

There is much scholarship documenting culturally diverse and ELL youths' disenfranchisement from STEM disciplines (Bang & Medin, 2010; Calabrese Barton, Tan, & Rivet, 2008; Rahm, 2014; Thompson, 2014). Indeed, much of this research describes formal

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STEM education as "racialized" and "gendered," and contends that formal STEM education tends to marginalize the funds of knowledge and experiences that culturally diverse and ELL youth bring to STEM learning environments. Further, such environments may provide few "identity resources" (Nasir, 2012) for youth to enable them to take up new roles or responsibilities that position them as competent or developing experts (Bell et al., 2013). Hence, there is a great need to understand how STEM learning environments can broaden these marginalized youths' participation in STEM in ways that afford, rather than constrain, the range of available identity resources.

The current challenge to equip students with 21st century skills includes the exploration of intersections among core subjects to prepare children for "the competitive, complex, and connected world they will inherit" (Partnership for 21st Century Skills, 2007, p. 2). An interdisciplinary approach provides students ways to develop more knowledge and skills and possess better mastery of the materials than discipline focused traditional programs (Bransford, 2000). Using funds of knowledge with inquiry-based learning, students can explore a trilateral collaboration in concepts, explanations, and learning outcomes that expand from collecting data and relevant information to include comparative learning, increase awareness of science as important to everyday life, and extend knowledge through translations of science into other spheres of knowing, intelligence, and communication.

We argue that if we are to expect students to apply "novel ideas to new situations," we must provide opportunities for students to practice science in many contexts (AAAS, 2009). Thus, this case study investigates how individual and collective STEM development can unfold in a cultural milieu that uses science as a framework to engage multiple intelligences in support of a collective, interdisciplinary learning culture. The study tracks how a STEM design grounded in multi-modal learning and science translation afford a STEM approach that is inventive, innovative, and meaningful for underrepresented ethnic minority children. By employing multi-modal, interdisciplinary methods with science translation, immigrant/ELL youth strengthened STEM interest and skills and increased STEM identity and STEM self-efficacy.

The Study's Goals and Objectives

During 2014-16, the Burroughs Wellcome Fund supported UBEATS (Universal BioMusic Education Achievement Tier in Science), an informal STEM program developed as an out-of-school intervention for immigrant children in Guilford County. (https://research.uncg.edu/spotlight/wild-music-festival-brings-immigrant-children-to-stem/). The project, a collaboration of the University of North Carolina at Greensboro's (UNCG) BioMusic Program and its Center for New North Carolinians (CNNC), the Greensboro Science Center (GSC), and the Guilford County School System, targeted children of immigrant families in the county, which has one of the fastest growing communities of new immigrants in the Southern United States; the majority coming from Central America and Southeast Asia, as well as Africa and the Middle East. (See Supplementary Materials).

Using an array of activities, the UBEATS student participants (Year 1: 50; Year 2: 81) in grades 3-8 studied music-making and animal communication systems as scientists. The program, led by UNCG Director of the BioMusic Program, professional teachers in STEM education and ELL, technology specialists, science center staff, a children's theatre professional (Year 2) and four immigrant high school student interns, created learning activities based on a BioMusic curriculum grounded in the National Education Standards (National Research Council, 1996). UBEATS programming was structured to include two annual one-week summer camps, each followed by a once-a-month three-hour club meeting over two academic years (AY) at the Greensboro Science Center (GSC). Student learning activities featured sonic communication in humans and other species, data collection of terrestrial and marine species, hands-on experiences with audio technology and analysis programs, and student research of families' signifying sounds from countries of origin.

UBEATS curriculum, content, and activities center on sonic communication systems and human music-making, an untapped or rarely employed resource for funds of knowledge. Based on BioMusic research (Gray, 2014), animal behavioral and communication systems, and multi-modal information processing, UBEATS science learning proceeded by examining sonic communication systems and music-making using comparative analysis, technology manipulation, and science translation. Because UBEATS defines sonic communication and music-making as a biotechnology, content and methods are designed to stimulate learners to explore sound-making as survival strategy, analogous music-like structures, and sound/time perception in themselves and other species, while exploring the evolutionary trail of communication systems in an array of acoustic environments. This approach enables children to use their innate musicality as a basic tool in discovering how animal communication relates to human music making, while enabling students to affirm habits of discovery and inquiry (Carrier, 2012). Thus, UBEATS STEM content reflects interdisciplinary, firsthand, multi-modal approaches to knowledge-building that are found to be hallmarks of powerful learning in formal and informal environments and key attributes of learning for preparation for the 21st century workforce (National Research Council, 2009, 2012, 2015).

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This Study investigated whether and how non-traditional STEM learning methods based in the exploration and production of communicative behaviors can promote and broaden STEM identity and STEM self-efficacy in English speaking immigrant and ELL children. Our work examined two broad questions:

1) Will using interdisciplinary cross-cutting BioMusic concepts and practices that exercise innate human musical capacities underlying environmental information processing, communication, and culture creation increase and improve the multiple domains deemed critical to STEM competence, identity, and self-efficacy?

2) Can science translation using practices grounded in both the arts and sciences enhance STEM identity and self-efficacy in immigrant/ELL youths?

Cross-Cutting Content and Activities

What is BioMusic? BioMusic is a multi-disciplinary field - biology, animal communication, ethnomusicology, music theory, neuroscience, physics, bioacoustics, and evolutionary biology - that studies music's biological and cognitive elements to explore relationships and meaning-making in humans and non-humans (Gray et al, 2001). BioMusic research focuses on meaning-making using auditory perception, including the semiosis of sound in the social environment, as well as commonalities of musical sounds in all species, in relations of sonic patterns, frequencies, rhythms, volume, structures, significance, and their role in biodiversity (Gray, 2015).

The UBEATS program content and activities, based on and elaborated from BioMusic curriculum developed with a National Science Foundation STEM education grant ("UBEATS," 2013) to the University of North Carolina-Greensboro (UNCG) and North Carolina State University's Kenan Fellows Program, engaged the students to:

- Explore aural non-verbal structured communicative behaviors in humans and other species;
- Participate in real-time activities/games that reveal how time, frequency, amplitude, and memory impact animal/human communication systems;
- Explore environmental acoustics in animal behavior, adaptation, and sustainability;
- Explore the musical brain as a neurological communication system;
- Explore relationships between animal communication behavior and physical properties of sound in diverse environments (soundscapes);
- Record local soundscapes and use sound analysis software;
- Utilize sound technology for data collection and for creative purposes;
- Explore innovative ways to use symbols to represent sound;
- Explore live animal husbandry and habitat requirements for real-time engagement;
- Provide STEM career events;
- Create Participation for families in STEM events;
- Present parent showcases;
- Design & produce translations of artifacts that blend aspects of creative expression and youths' interactions with the natural world.

Specifically, this study looked to design ways to affect the significant impacts of cultural, economic, and developmental differences of immigrant/ ELLs while broadening and strengthening their goals, expectations, and future thinking. To address these, UBEATS developed learning activities in the second year that supported the translation of science knowledge as a strategy for immigrant/ELL learners to personalize STEM relevancy, convey their knowledge, and build self-efficacy.

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UBEATS Methods, Figure 1

Build Competence in STEM skills	• Explore aural non-verbal structured communicative behaviors in humans and other species. • Demonstrate that using symbols to capture auditory events enables students to develop STEM analytical skills and develop technology skills. • Explore physics of sound and sound's physical/neurological processing pathways for multiple species. • Explore the effects of environmental sonic changes, adaptations and behaviors that enable animals (including humans) to survive in changing habitats. • Explore how animals meet their needs by using sonic behaviors in response to information received from the environment. • Experience and practice audio research techniques and methods in controlled and wild environments.
Build Competence in using technology	• Offer opportunities to record sonic data in controlled and wild environments using diverse recording technologies (terrestrial and marine). • Experience sound analysis techniques that use symbols to capture complex auditory events.
Build STEM Identity	• Offer multi-modal opportunities to develop STEM enthusiasm, conceptual and technical knowledge, and STEM identity. • Offer students opportunities to engage in public presentations, to share their research and knowledge with their families, to build interest in STEM.
Build STEM self-efficacy	• Build on motivating and engaging children through their innate interests in music, animals, and team-based problem solving. • Engage in the process of science translation.
Broaden Awareness of STEM across disciplines	• Focus on the physical properties of sound and how auditory systems are used for observation and sense-making. • Provide access to live animals at the GSC to increase STEM knowledge about the role of sound in animal behaviors, sustainability, management, and biodiversity.
Encourage Positive Attitudes toward STEM oriented behaviors and relevance	• Provide research activities online, at home, and at UBEATS project sites that link systems thinking about sounds to children's everyday lives including humans, other animals, and sound environments.
Increase Knowledge of STEM degree paths	• Utilize opportunities in UBEATS lessons to provide students with pathways for sound-related degrees and future career information. (bioacoustics, acoustics, audiology, etc)
Stimulate Interest in STEM Careers	• Provide access to in-person early career STEM role models in diverse career paths. • Provide experiences with new, non-verbal time/sound therapies and medical research.

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Year One Methods

YEAR ONE: UBEATS initial focus centered on the physical properties of sound and how the auditory system is used for observation and sense-making in humans and other species. Children used iPods, field recorders, a shotgun microphone, and a hydrophone to experience diverse sound environments and learn about ways that sound technology and sound analysis techniques provide research opportunities. Year One's activities at UBEATS camp, at a field trip to a state park, and at AY club meetings at the science center offered multiple opportunities to explore wild environments and animals using symbols to capture auditory events and enabled students to develop analytical and technology skills to link systems thinking about sounds of humans, other animals, and sound environments to their everyday lives. To increase STEM knowledge about the role of sound in biodiversity, the GSC provided access to their wide range of resources, including habitats of resident terrestrial and marine animals, enabling students to collect data, sound recordings, and observational details during changing seasons and environments.

Information about career paths and opportunities was provided by invited early career scientists in bioinformatics, wildlife preservation, and neuroscience, as well as animal caretakers at the GSC who gave in-person presentations at club meetings about the scope of their careers, educational arcs, and how sound is used in their field. Each speaker included detailed information about their personal progression from high school to higher education, and how and why they followed their career paths.

Building Family Involvement. UBEATS students and families received free annual passes to the GSC during Year One and Two to encourage family visits and to support students' interests beyond UBEATS planned learning activities. To enable greater family participation at annual capstone events (The Wild Music Festivals), immigrant community leaders greeted families, and free transportation and welcoming signage in 5 languages was provided. During each year's Wild Music Festival, participating children presented a special program in the GSC's OmniTheater for their families supported by multiple translators, provided an overview of their UBEATS activities, and concluded with a reception for the children and their families.

Student Documentaries. Four high school immigrant students (countries of origin: Liberia, Burma, Mexico, and Vietnam) served as mentors during Years One and Two, supporting learning activities and working with the UBEATS Learning Leaders. Working as a collaborative team and mentored by media professionals, they also designed and produced two annual Student Documentaries that reflected their perspectives on the meaning and importance of UBEATS. They learned video production and editing techniques, interviewed key personnel, and shot additional video at community sites for each year's five-minute UBEATS documentary (UBEATS H.S. Student Mentors Documentary," 2015).

YEAR One - Capstone Event. The Wild Music Festival's (WMF) inclusion in the GSC's public offerings, provided ways for typical science museum visitors and families to learn about the children's UBEATS activities. Year One's WMF featured exhibits of students' recordings of GSC resident species with a site map of the recordings and an exhibit of audio samples based on the children's research of their family elders' memories of signifying sounds from their countries of origin. This also included a world map of specific countries represented. Participating students were tasked with explaining their STEM experiences and new knowledge to their families and the public.

YEAR ONE Results and Discussion: The first year's data, using surveys and focus groups following the opening camp experience, indicated the following:

- 91% of participants indicated increased interest in doing science;
- 85% indicated increased understanding of science's importance in their lives;
- 65% indicated science is a favorite subject;
- 82% indicated that they had good feelings about science;
- 78% indicated an increased recognition of science's importance in understanding the world;
- 82% reported increased interest in pursuing future science careers.

These results provided data that the project's educational approach using innovative multi-modal BioMusic curriculum as the primary learning stimulus presented a potent and important opportunity to increase immigrant students' interest in STEM learning. However, transitioning into the academic year's monthly

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club meetings presented challenges in continuity of attendance and therefore retention of conceptual learning. At the WMF, the planned opportunities for student sharing of STEM experiences and learning with the public and families were daunting. UBEATS staff found that most children retreated and preferred not to participate in this typical mode of scientific exchange. Girls, particularly, while enthusiastically engaged in UBEATS activities throughout Year One, avoided individual participation in public events at the WMF.

During UBEATS Year One of the AY club meetings, the Burroughs Wellcome Fund's standard student evaluation surveys were used and produced results asynchronous to the UBEATS staff observations. Questions were raised whether the standard survey data collected during the camps and monthly meetings captured an accurate picture of the children's learning, attitudes, and future thinking. After reviewing the language of the surveys in that context, UBEATS and BWF staff agreed that adjustments were needed for this population. Focus groups were increased and during surveys, staff could clarify meanings for the children, and that surveys may need to be read aloud to individual students, and as needed, to explain the intent of a question.

UBEATS staff Year One reviews of the children's progress identified perceived challenges to the children's future opportunities in STEM learning and careers. These included weak family support, lack of self-confidence, fission/fusion social behaviors undermining collaboration, and confusions about American cultural expectations and opportunities. [NOTE: 'fission/fusion', a concept from animal behavioral sciences, describes fluid/changing alliances that occur often and impact relationships and outcomes.] As noted in research of STEM education and culturally diverse immigrant communities:

> In many societies, cultural norms prioritize respect for teachers and other adults as authoritative sources of knowledge. In other words, validity of knowledge is often based on the validity of its source, rather than the validity of knowledge claims. Children who are taught to respect the wisdom and authority of their elders may not be encouraged to question received knowledge in ways that are compatible with Western scientific practices or normative school science (Lee et al 2005).

While the UBEATS students journaled regularly, observations revealed that they preferred alternate, non-verbal means reliant on other intelligences to convey comprehension of their STEM learning. Drawing, gestures or dance movements, music-making, rapping, imitating sounds, and finding correlations to sound environments beyond UBEATS programming signaled untapped opportunities for these children to convey STEM learning.

Considering both the challenges and opportunities, UBEATS staff proposed a new learning design -science translation - as an intervention that could use the children's innate funds of knowledge with their acquired UBEATS STEM learning to counter the significant impacts of cultural, economic, and developmental differences. A science translation intervention employing children's theatre techniques was planned to assist with broadening and strengthening STEM learning, and support STEM identity and self-efficacy.

Year Two: Method and Rationale

YEAR TWO: Activities conducted in the second year utilized non-traditional STEM methods to engage UBEATS participants, comprised of both returning students and new arrivals, in thinking about, learning, and conveying STEM knowledge through the process of science translation. Using a targeted goal of producing a collaborative student-centered and created staged theatrical production to convey to families and the public the relevance and meaning of science, the study tested this method as a possible intervention to build STEM self-efficacy. By engaging student interest in using observation and listening skills, technology, and critical argument, students explored how to reinterpret science as valid story. This new approach leveraged Year One data showing that the UBEATS population, while interested in science (81.8%), was also thinking about jobs in arts and entertainment (54.5%). The data also showed that the children thought UBEATS helped them learn science better (63.6%) and helped them feel better about learning science (72.7%). However, more than half did not see science's relevance to everyday life (54.6%). Thus, the planning for UBEATS Year Two summer camp and its successive AY club activities focused on developing an alternative pathway, the translation of science knowledge, to leverage creativity - a critical aspect of science research- and provide multi-modal opportunities for students of diverse cultural and ethnic backgrounds to personalize and express STEM learning and its relevancy while engaged in collaborative research.

Year Two: Methods

All of Year Two's learning activities centered on science translation as the impetus for student research activities, analytical thinking, and abstract planning. Building on the students' previous research of sound environments, animal husbandry and communication, they were tasked with creating, making, and presenting STEM concepts through the medium of puppetry. This active, learner-centered process employed a hands-on, makerspace approach that challenged students to examine scientific questions in detail, take and defend perspective, and make sense of science's impactful role on life.

We hypothesized that: 1) this generative process of science learning and translation could imbed a creative, collaborative, and maker approach to STEM learning; 2) the process of dynamic engagement among and between children could heighten scientific discourse that would deepen the STEM experience; and 3) the creative process of shared commitment to inquiry and collaboration, aligned with STEM knowledge creation, could develop a path to STEM self-efficacy.

The methodology focused on the children developing story lines to engage audiences in the science of three specific animal species, selected by the children from resident species at the GSC, that they had ongoing access to and had engaged with during Year One. Mentored by a children's theatre professional, the children focused their research of sound's impact on behavioral, communicative, and husbandry sciences as the basis for story creation, character development, sounds and sound tracks, costuming, scenery, and eventual performance. This process began during the 2015 summer camp and included a field trip to a professional puppet company where the children explored representation, allusion, and movement – elements continued during UBEATS AY club meetings.

Children chose three species for story development and self-selected to join an animal's team - 'tigers' or 'gibbons' or 'penguins' - making themselves experts, keeping detailed records of their research, and translating their knowledge of that animal to others. Learning activities were designed to support the authenticity of the developing story lines through questioning, debating, and reviewing scientific facts, and by increasing STEM knowledge of the three chosen species' behaviors, sound environments, conservation, and sustainability issues at the GSC and in the wild. Using observation skills, recording ambient and focused sounds, interviews with animal caretaking staff, and behind-exhibit observations, the students engaged as scientists to incorporate the complexity of sound's influence on animal behavior, survival, and well-being.

As students demonstrated little to no prior experience or knowledge of puppetry, drama, and mask work, students were first exposed to examples of each of these before being asked to apply their STEM learning outcomes. During the Year Two summer camp, students experimented with making puppets from every-day found objects. Working in small groups, they created simple story narratives using common household objects to explore how creative and imaginative work is accessible with no previous experience. Additionally, videos and pictures of professional productions combined with the summer camp's field trip to the professional puppet company provided students both the opportunity to experience professional manipulation of puppets and masks and first-hand physical manipulations with those objects. These activities further challenged the children to explore and compare the physics of movement in humans and animals while generating excitement about creating their own puppets and stories.

This translational process generated science narratives during UBEATS AY club meetings that revolved around two major drama-in-education practices: 1) create a student-centered environment that places students in-role as the expert; and 2) through exploratory generative activities, develop students' ideas, STEM knowledge and inquiry, and empathetic responses to an animal's behaviors, perspectives, and environmental needs.

This process requires a balance between input of both Learning Leader and students—a "flexible framework" that works to build on children's ideas. Such a supportive environment affords children the safety to "make a bridge for them[selves] between their own experiences of the world and the meaning of the drama, so that both insight and understanding arise from the activity." (O'Neil & Lambers, 1982, p. 10). To this end, games and activities that leveled the power dynamic between Learning Leader and student

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simultaneously engaged and supported student cognition and its physical expression and encouraged inquiry-based learning to help students more accurately represent their animal's story, thereby building agency.

Second, the students' generative processes were supported and guided by the noted drama pedagogue, Constatin Stanislovski's, concept of what if—a phrase that is fundamental to all learning and that serves to jettison unnecessary imposed parameters or limitations. What if is used "as a lever to lift us out of the everyday life on to the plane of imagination." (Stanislavski, 1989, p. 59). Prompts, such as "what if 'you' [role playing as your animal] were to encounter a predator", were used to propel students into scenarios that engaged their knowledge of animal behavior and communication, and environmental issues while stimulating explorations of their animal's options and possible actions. Students generated scientifically grounded problems that their animal might encounter and the individual, group, and environmental options available to resolve them. They were challenged to define what their animal might 'want' using their STEM knowledge, and what was stopping their animal from achieving the objective. This process built the framework for the students' improvisations in-role as their animal.

Each group's narrative and major characters encompassed story-telling's basic protocols of antagonist, protagonist, and supporting characters. Through a guided design process, students began construction of representational puppets, masks, and habitats. Similar to the children's first introduction to puppetry, each animal group's characters and scenery began with simple materials that demonstrate puppetry's accessibility: cardboard, craft paint, and jersey knit fabric from recycled t-shirts. To increase family participation and interest, additional efforts at local community centers engaged parents and families in scene construction and costume building.

The role of sounds and sound-making in animal behavior, for survival and in environmental soundscapes, was the key provocative element for the narratives. Hence, the students focused on defining and representing the sounds that corresponded to their story. Each narrative's soundtrack was integrated as live Foley sounds made by the students, and as recordings that the students made of themselves, and/or through found sound files.

For the capstone performance of Year Two's Wild Music Festival, and to further emphasize the role of sound for the public and family members, audiences were asked to provide additional story-telling sounds cued by card prompts using icons instead of English words. Audience-provided sounds combined with the planned soundtracks to integrate environmental and animal noises critical to the telling of each story and were rehearsed with the audience just prior to each animal's puppet story performance.

Planning and Coordination of UBEATS Activities. The progression of the children's STEM learning around important information about their animals' sonic environments and behaviors with their evolving stories shaped the second-year's curriculum. The interdisciplinarity of the instructional team provided important, critical resources for the design and implementation of the programming and activities. The team's expertise in BioMusic, STEM education, theatre education, music education, ELL learning, and technology instruction helped shape resources in three areas - species education, story building and puppetry, and research of sound and/or music – anticipated and generated activities that supported the goals and objectives of the study's plan including the integrated scaffolding of unified learning sequences. Building on UBEATS first-year concepts and knowledge, relevant new information and activities were incorporated in the learning strategies to leverage conceptual learning across the continuum. Technology continued to play a significant role not only as a learning tool but with added importance for layering the sonic dimension into soundtracks for the puppet shows. Students used iPods to record the show's targeted species at the GSC and some of the sound effects eventually used in the shows. Additionally, sound recording apps were sourced to learn and review sound terminology, such as pitch/frequency and patterns, within the context of each animal's environment and communication frequency range of hearing and sound-making. Embedded multimedia played through a smart board helped students understand the complexity of their animal's habitat and the prey/predator relationships in those sonic habitats.

Throughout UBEATS programming, learning activities included building expertise in contextual knowledge and explicit but differentiated academic vocabulary used in different disciplines, specifically music, science, or technology. Student learning evolved collaboratively and competitively and was reinforced using appropriate scientific methods to inform all multi-modal learning contexts. This process provided multiple but meaningful ways for diverse learners to participate and to convey STEM knowledge to peers and staff.

The final capstone event, the second Wild Music Festival, at the GSC featured two performances of three student-designed, student-created, and student-performed puppet shows in a theater setting; one presented for their families and one for the public. By performing their science translations as a collaborative team, students invested in the quality and success of their team's storytelling and its performance, often advising one another about how to improve the performance while engaging in conversations about the meaning and importance of their animal's story.

Discussion

The second-year data suggest that the goals and objectives set for immigrant ESL and ELL children in STEM programming can be addressed in non-traditional, alternative ways. First, UBEATS wanted to know if these children developed STEM knowledge, expertise, and self-efficacy through the process. Results show (survey results in supplemental materials) that 60% to 80% acquired complex understandings of the integration of animal behavior, animal communication, environmental factors, and issues related to conservation and sustainability. Further, the children developed and relied on a suite of fundamental scientific process skills to address questions about their animal including:

- observation 75%
- recording 66%
- writing about 56%
- reading about 50%
- searching the internet 41%

Finally, key impacts of UBEATS programming included positive attitudes:

- about science (77% yes, a lot or yes, a little)
- about using science process skills (77%)
- about interest in animals (82%)
- interest in nature (88%)

UBEATS experiences also changed:

- ideas about what scientists do (84%)
- student perceptions of improved technology skills (84%)

All represent significant outcomes for building STEM self-efficacy.

Conclusions

This 2-year case study pursued alternative methods centered on employing diverse learning styles and multiple intelligences for culturally and linguistically diverse students. Specifically, non-traditional methods that exploit communicative behaviors served as a means to build STEM self-efficacy, identity, and learning in children who typically underperform in traditional classroom environments. In an innovative interdisciplinary and progressive cycle of learning activities, students acquired, used, and relied on STEM skills and academic vocabularies of multiple disciplines to realize a larger goal, a learning output they designed and performed for a valued audience. This learning design promotes students' communication of their understanding of STEM concepts while practicing skills and arguments used by scientists.

The larger arc and format for these learning outcomes capitalized on integrated, interdisciplinary multi-modal STEM content and a science translational process and performance. This approach leveraged non-verbal communication systems important to multiple fields of science, to the arts, and to sports but underrepresented in most academic learning environments. Its timeline allowed multiple accommodations for the Learning Leaders by providing: 1) adequate support for planning and preparation; 2) multiple sessions of cross-talk that developed an integrated team perspective.

For the children, self-efficacy in learning is understood to be central to enabling participation in the STEM pipeline. Research repeatedly shows that student self-efficacy, or a student's belief about their ability to be successful in a specific domain, is strongly related to "internal beliefs and experiences (that) combine to influence their ideas and expectations about their own capabilities with respect to STEM" (Dorsen et al, 2006). But recognizing oneself and others as capable, valuable, and competent in STEM remains an allusive outcome particularly for these children who typically receive disappointing performance feedback, experience educational inequities, grapple with cultural norms regarding expertise, and generally fade into the background or disappear when it comes to finding a voice in the formal or informal classroom (Betz & Hackatt, 2006; Johnson-Ahorlu, 2012; Lent et al, 1994). The prevailing challenge remains how to stimulate young minds in ways that enable immigrant children to change preconceptions about their abilities and futures in STEM, while leveraging initial interests in science and curiosity about the world. To counter and restructure these cultural and conceptual patterns, UBEATS explored alternative methods and pathways for these children to think about, process, and participate in science learning.

Traditional approaches to STEM learning for immigrant students often channel activities grounded in vertical thinking outcomes - those associated with learning rules and right/wrong correlated choices. By suspending judgment and allowing multiple versions and rearrangements of information, the UBEATS students came to rely on their expertise, science knowledge and research, as well as their science processing skills while negotiating collaboration and innovation. This restructuring of the learning environment amplified opportunities to reinforce the value of inquiry on multiple levels in a re-imagined makerspace. Thus, by encouraging generative thinking, UBEATS students experimented with concepts and processes that challenge limiting parameters, categories, classifications, and labels, eventually finding new relevance in creating substantive translations of the science.

Learning research confirms multiple valid pathways to learn, think, and communicate science. The UBEATS intervention designed and tested a novel science translation method for diverse cultural and linguistic students using multiple intelligences in generative inquiry processes to expand how learning, thinking, and ‘doing’ science can take place. By enabling these children to develop a ‘voice’ within a STEM learning context, they controlled their success and science became fun and relevant to them and their families. The outcomes suggest that these positive experiences provide personal relevancy, increased STEM interest, and engaged future thinking about STEM - all critical elements for building self-efficacy in STEM.

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Supplementary Materials Include:

Participant Surveys, Years 1 & 2
Survey Results
Figure 1. Participants by Country of Origin
Figure 2. Participants by Gender
Figure 3. Participants by Grade Level

A New Paradigm for STEM Learning and Identity in Young Immigrant and English Language Learners: Science Translation As Interdisciplinary, Multi-Modal Inquiry

SUPPLEMENTAL MATERIAL

1. Surveys Results – Year 2

Findings from Survey
Spring 2016
Figure 1: Percentage of Students Who Reported Engaging in Specific Science Behaviors in Relation to the Animal They Studied

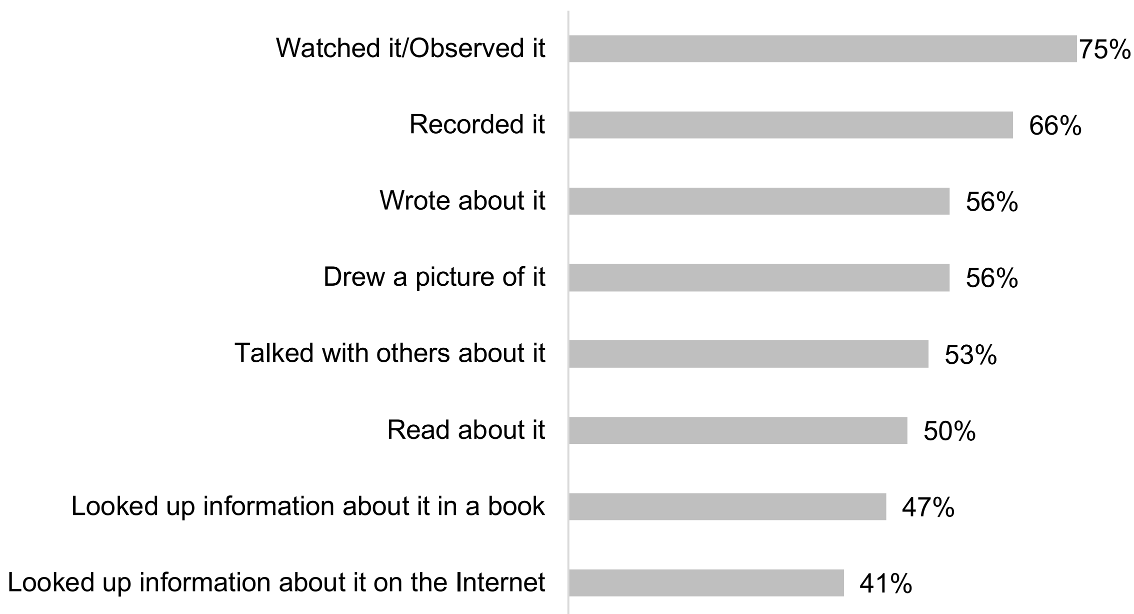


Figure 2: Students' Self-Identification of Their Knowledge Level of Their Animal Relative to Their Friends Not at UBEATS

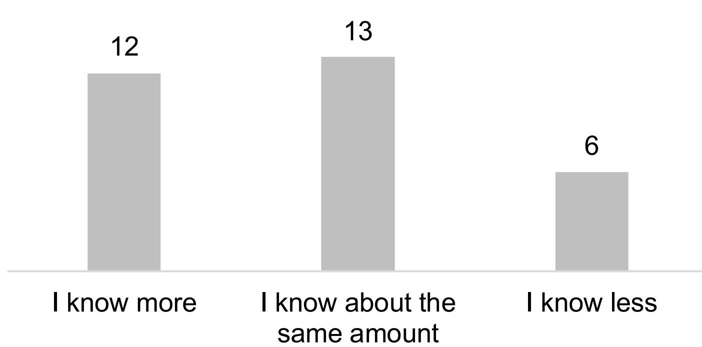


Figure 3: Degree to Which Students Indicated That Being a Part of UBEATS Had the Following Impacts

[Scale: Yes - a lot (3), Yes - a little (2), Not really (1)]

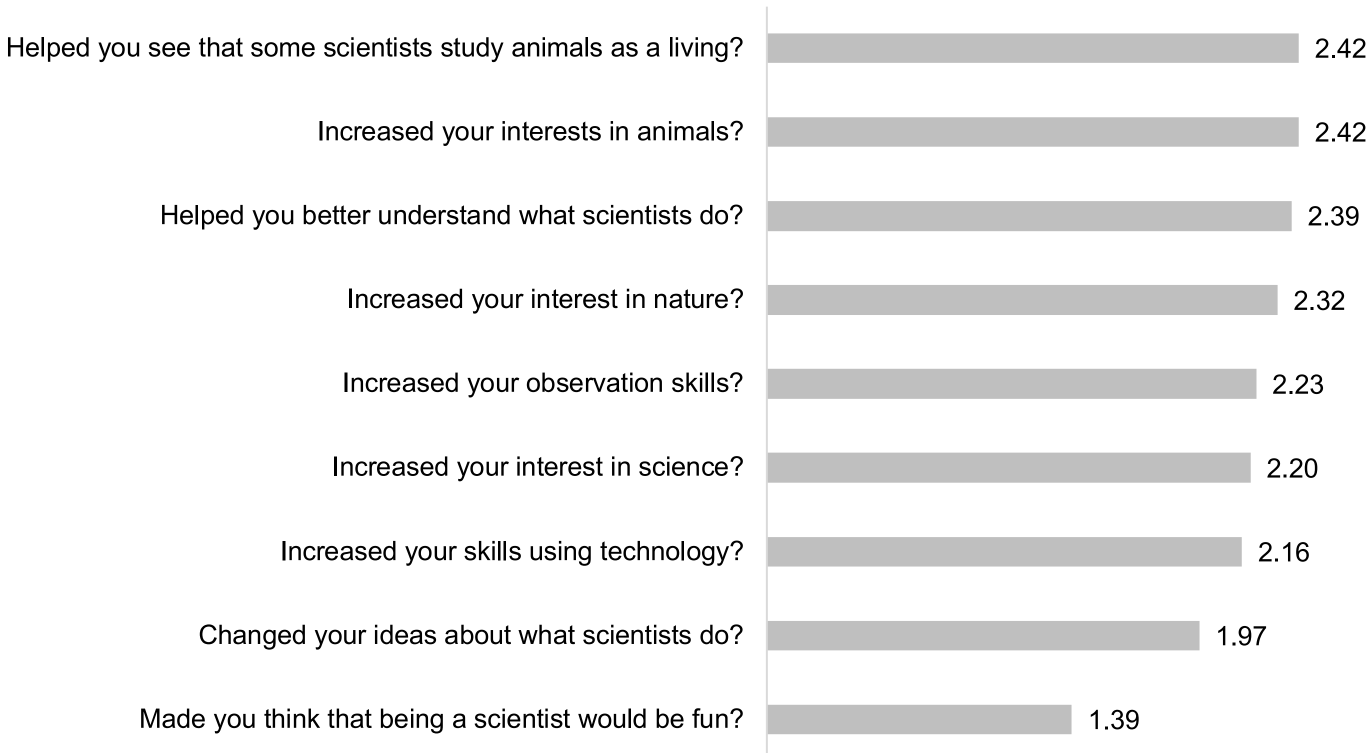
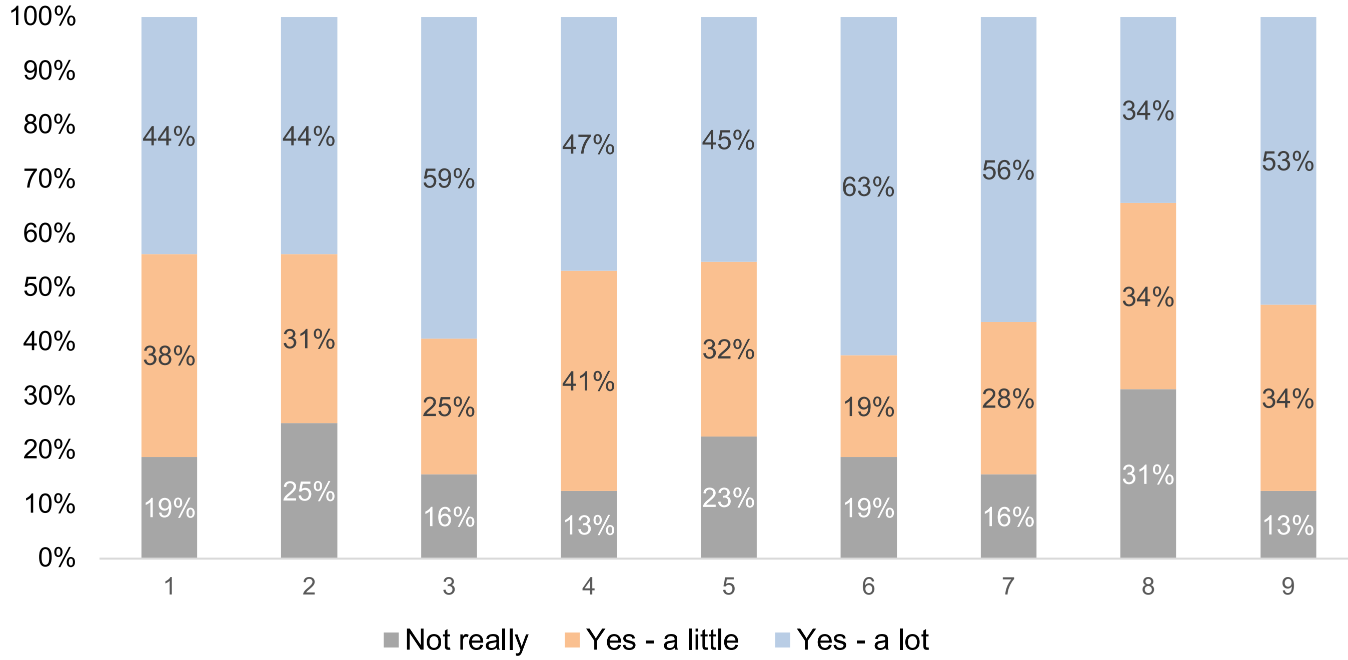


Figure 4. Bar Chart of Survey Results



Student Survey Questions

(Survey to be read out loud)

1. You have been studying different animals as part of the PROGRAM this year. Please indicate what you know about your animal by filling in the chart below.

My animal is:
My animal eats:
My animal lives in:
Other animals that also live there are:

My animal uses sound to:
The sound my animal makes is:
Dangers to my animal in the wild are:

2. Are there any other things that you can tell people about related to your animal?_______________________________________

3. When scientists want to learn about an animal, they may do many things such as those listed below. Which of the things did you also do to learn about your animal?

Watched it/Observed it	Talked with others about it
Looked up information about it in a book	Recorded it
Wrote about it	Looked up information about it on the Internet
Read about it	Drew a picture of it

4. Do you think you know more, about the same amount, or less about your animal than your friends who are not at UBEATS?

I know more	I know about the same amount	I know less

5. Has being a part of UBEATS:

a) Increased your observation skills?	Yes, a lot	Yes, a little	Not really
b) Increased your skills using technology?	Yes, a lot	Yes, a little	Not really

c) Increased your interests in animals?	Yes, a lot	Yes, a little	Not really
d) Increased your interest in nature?	Yes, a lot	Yes, a little	Not really
e) Increased your interest in science?	Yes, a lot	Yes, a little	Not really
f) Helped you see that some scientists study animals as a living?	Yes, a lot	Yes, a little	Not really
g) Helped you better understand what scientists do?	Yes, a lot	Yes, a little	Not really
h) Changed your ideas about what scientists do?	Yes, a lot	Yes, a little	Not really
i) Made you think that being a scientist would be fun?	Yes, a lot	Yes, a little	Not really

Findings from Survey

Spring, 2016 (n=32)

Table 1: Number and Percent Providing Correct Responses

	Gibbon (n=14)	Penguin (n=10)	Tiger (n=8)	Total (n=32)	Percent
My animal lives in:	11/14	9/10	7/8	**27/32**	84.4%
My animal eats:	9/14	9/10	8/8	**26/32**	81.3%
Dangers to my animal in the wild are:	10/14	8/10	6/8	**24/32**	75.0%
The sound my animal makes is:	10/14	6/10	7/8	**23/32**	71.9%
My animal uses sound to:	6/14	6/10	8/8	**20/32**	62.5%
Other animals that also live there are:	3/14	10/10	6/8	**19/32**	59.4%
Additional information about my animal:	5/14	5/10	6/8	**16/32**	50.0%
Total:	**54/98**	**53/70**	**48/56**	**155/224**	69.2%

Percent:	55.1%	75.7%	85.7%	69.2%

Sample Responses

Other animals that also live there: Penguin Seals, fish, shrimp, orcas, lions

My animal uses sound to: When baby is come, Talking to each other, Danger is coming, Trouble is coming, Communicate with their parents and friends, To find another tiger

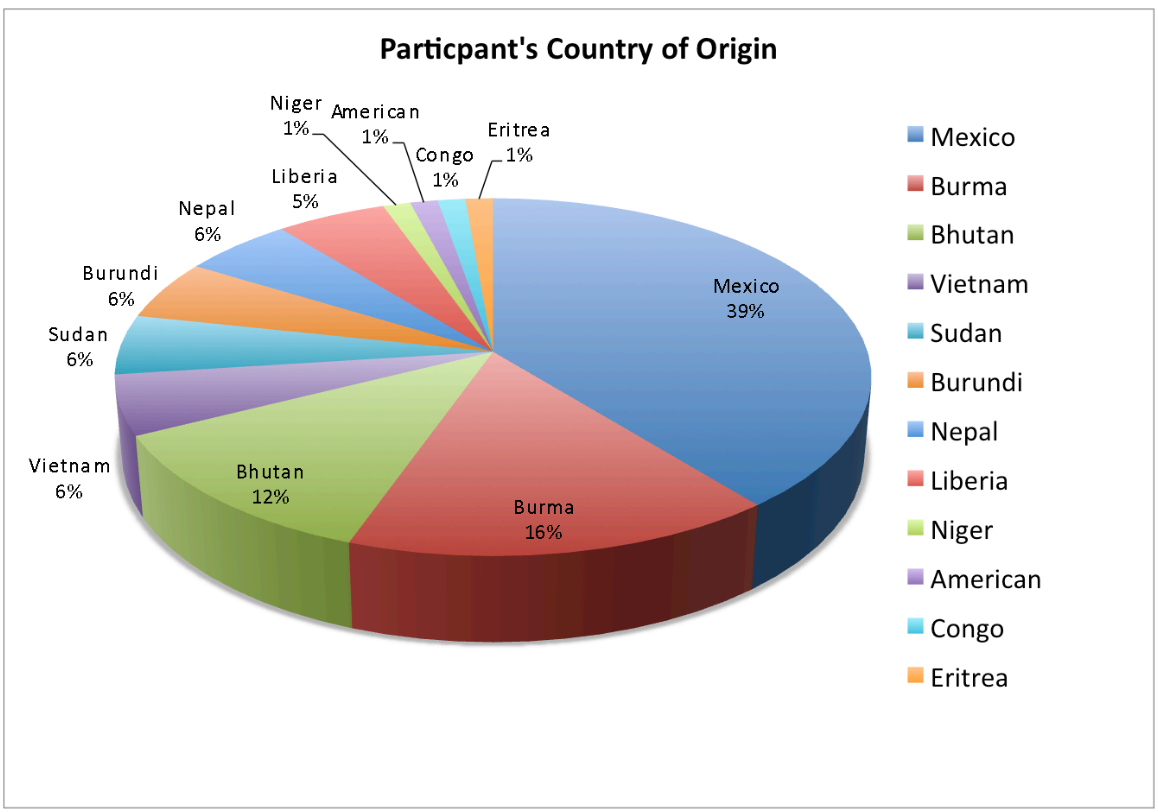
The sound my animal makes: High and low pitch, A loud sound, Donkey sound, Owl sound, Roar, Chuffing

Dangers to my animal in the wild are: People because they cut the trees, People hunting them, Whale, Leopard seals, orca, and sharks, Lions

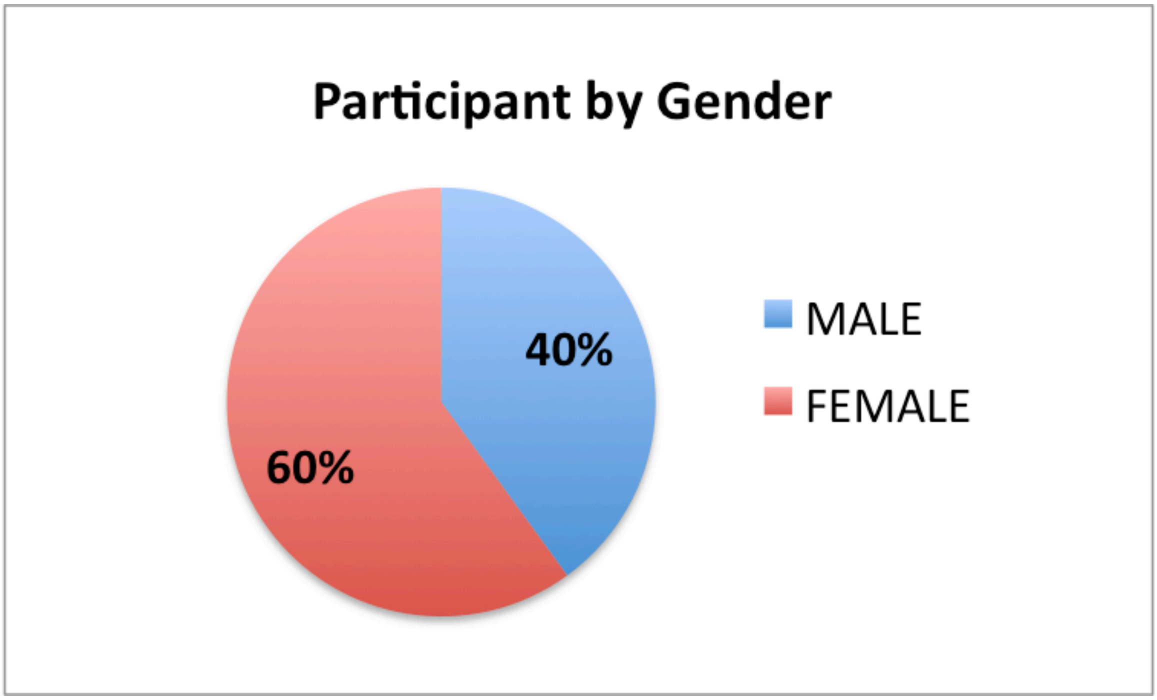
Additional information about my animal: A lot of people think the gibbon is a monkey but it is not because gibbons don't have tails; They look like little real kids. They eat using their hands. They climb trees; Brown fur, they have families, live in zoos; The mom and dad take turns taking care of the baby while one parents searches for food; I can tell them that penguins are very protective creatures, and they use guarding and going to find food strategies; They climb trees; My animal runs from danger or hides; They are very good. They like to eat meat and chicken.

Figures 5a, b, c. PROGRAM Participant Demographics

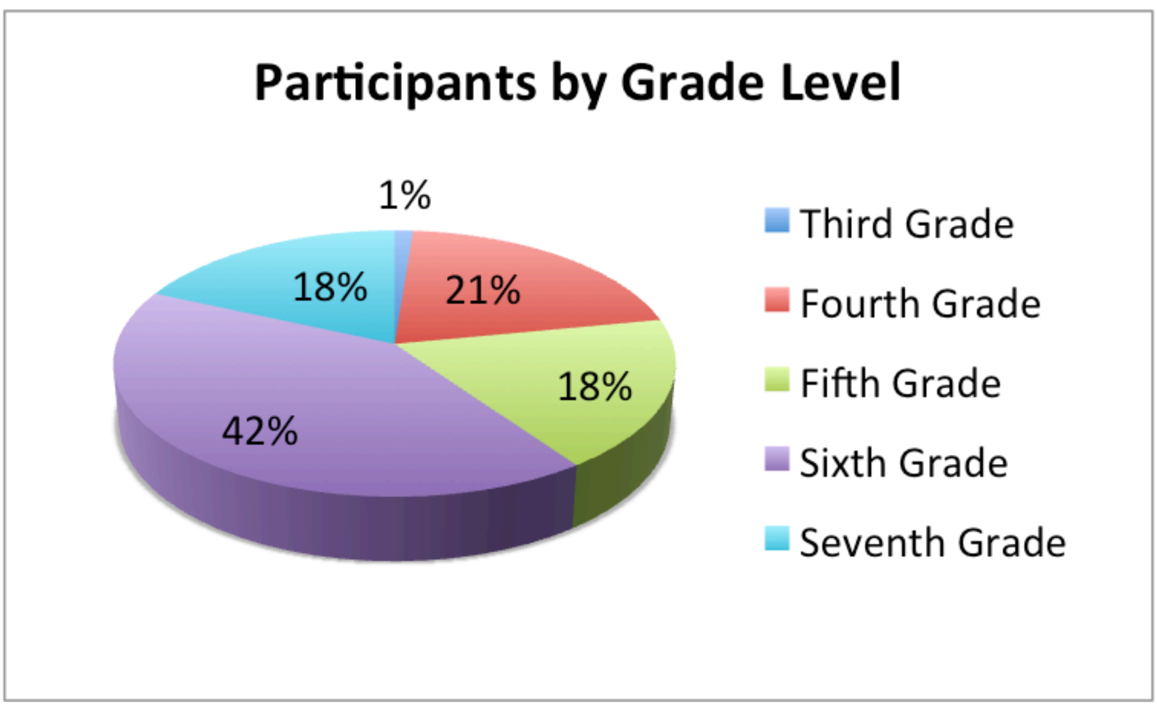
a. Country of Origin



b. Gender



c. Grade Level



KENAN FELLOWS PROGRAM FOR TEACHER LEADERSHIP

Journal of Interdisciplinary Teacher Leadership

ISSN 2474-7432

2019, Vol. 4, No. 1

Translating Research to Practice on Individual and Collective Mathematics and Science Identity Formation: Pedagogical Recommendations for Teachers

Dr. Rebecca Hite, Texas Tech University and Dr. Mona Tauber, The Langley School

ABSTRACT

Recruiting students to science and mathematics fields continues to be a nationwide issue, resulting in a dearth of individuals to fill these present and future careers. Novel interventions, especially within the K-12 space, call for a move from content acquisition to the formation of individuals' identity that particularly fosters science and math interest and persistence. Identity research has evidenced results, yet greater communication is needed between the research and practitioner communities to realize the potential of cultivating collective science and mathematics identities in the classroom. In this paper, we bridge these spaces by describing the potential student affordances beyond individual identity formation to that of collective (classroom-level) identity formation considerations by K-12 teachers' within mathematics and science. Specifically, we explore how traditional K-12 classroom structures may reinforce stereotypes and hinder collective mathematics and science identity formation, whereas reform-oriented classroom structures that employ legitimate peripheral participation within a community of practice enable them. Last, we recommend pedagogical interventions to practitioners that promote collective student opportunities to co-construct skills specific to mathematics and science communities as a strategy to foster collective mathematics and science identities. Collective identity formation can provide K-12 classroom teachers pedagogical strategies for additional opportunities or enhanced experiences for students to co-construct and reinforce individual identities in math and science.

Keywords: *communities of practice; identity; mathematics education; science education; research to practice*

Introduction

The concepts and constructs related to identity have long held importance in learning; numerous research studies have sought to better understand the development of identity in fostering affinity to various groups (Gee, 2000; Taylor, 1989). Other studies have attempted to gain insight into identity's role in consequential generation of interest and persistence in educational endeavors (Billett & Somerville, 2004; Norton & Toohey, 2011). The examination into identity has been of recent importance to Science, Technology, Engineering, and Mathematics (STEM) education as STEM fields remain an urgent and present economic need (Kuenzi, 2008; National Academies of Sciences, Engineering, and Medicine, 2016), spurring high level policies like the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science or COMPETES Act (Furman, 2013) and P-20 educational reforms to strengthen the American STEM pipeline (National Research Council, 2011). The majority of current STEM reforms are designed to advance students' knowledge within the STEM domains (Kelley & Knowles, 2016). Yet, the National Academy of Engineering (NAE) and the National Research Council (NRC) have called for research on strategies to cultivate STEM identity to improve the recruitment, retainment, and perseverance of students in STEM disciplines (2014). A STEM identity is defined as the ability to view oneself as a legitimate participant in at least one of the four STEM subjects and how the "individual [is] making personal meanings associated with their identity along with the cultural impact of social meanings on these various identities" (Hughes, Nzekwe, & Molyneaux, 2013, p.1980).

Cultivation of a STEM identity is thought to be important for K-12 students, specifically women and racial/ethnic minorities that are underrepresented groups within STEM, to engage in STEM subjects and careers (Carlone & Johnson, 2007; Espinosa, 2011; Johnson, Brown, Caroline, & Cuevas, 2011). For example, girls start to lose interest in science and mathematics in middle school (American Association of University Women [AAUW], 2010). A reduction of interest in identity within the K-12 grades is thought to increase the

ISSN 2474-7432
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gender gap in STEM test scores, encourage fewer women to take advanced STEM courses, and lower overall female participation in STEM within college and later careers (AAUW 2010; Spielhagen 2008). The suggested gender dearth by the NAE and NRC in STEM identity research (2014) suggests further discourse is needed, given much of what has been published in this space has examined students as individual agents in the formation of a STEM identity.

The exploration of the locus of identity formation in mathematics and science education—from individuals to that of a collective mathematics or science identity— that is presented in this paper, is not based on new research. It instead, draws on prior work in social psychology by Rogoff (1990, 1995), Cole and Engeström (1993), and Wertsch (1993) to shift the focus "from an individualistic conception of agency towards a more social understanding of the individual" (Billett & Somerville, 2004, p. 310). Lave and Wenger (1991) brought attention to the central notion of identity formation for new learners within groups of people in a shared endeavor or profession, labeling this concept as a Community of Practice (CoP). They, along with other scholars, have demonstrated that both individual and group identity is inseparable from learning (Buysse, Sparkman, & Wesley, 2003). Subsequent sociological research has helped further shift the view of identity to social practice and discourses of members within multiple communities rather than pre-formed identities held by individuals, exclusive of group membership (Benwell & Stokoe, 2006). The work of mathematicians and scientists is built within CoPs via enculturation of novices, alongside experts, into the authentic practices of mathematics and science, respectively. This suggests science or math identity is developed through apprenticeship-based opportunities, where learners observe and participate in authentic research (Bell, Blair, Crawford, & Lederman, 2003; Lave and Wenger 1991; Sadler, Burgin, McKinney, & Ponjuan, 2010; Wenger 1998).

This paper will examine why collective identity is important to K-12 learning in mathematics and science, as well as identify classroom interventions, involving pedagogical shifts that may foster collective mathematics and science identity formations. The intent of paper is not to reconceptualize identity, argue aspects of individual or collective identity or identity's relationship to science or mathematics, nor is it to offer new empirical data to this extant body of knowledge. Rather, our intent is to bridge the gap between research that often resides at the large scale, among governmental entities and research institutions and practice that offers a guide to science and mathematics K-12 teacher practitioners who have interest in identity research and wish to lead in their classrooms by enhancing their curriculum and instruction with individual and collective (classroom-level) identity-fostering strategies. Since most American K-12 learning environments are typically structured with a teacher and students learning math and science together, it is logical to invite and discuss how K-12 teachers' classrooms may help foster collective mathematics and science identities for students. Moreover, the National Academies of Sciences, Engineering and Medicine (2015) has recommended that teachers should be involved in the use of research, where their engagement in research-based reform should be contextualized within their classroom practices. We address this call by first defining identity, both individual and collective, discuss its affordances in science and mathematics education, and then encourage teachers to engage in identity-based reform practices through tangible pedagogical strategies.

Identity and the K-12 Classroom

The research literature has long explored individual identity as a critical feature of the knowledge-building process or learning (Beatrice, 2010). We both acknowledge and appreciate the diversity of thought around the concept of identity. However, we employ the conceptual understanding of identity as viewed by situative scholars as shared interest (Wenger, 2011) and a sense of belonging and commitment (Handley, Sturdy, Fincham, & Clark, 2006) within a CoP. This stance permits viewing identity as it relates individually and collectively to a domain, like science and mathematics. Through this lens, we also perceive identity formation through Lave and Wenger's (1991) legitimate peripheral participation, where novices develop expertise through authentic learning opportunities via social engagement with experts. Legitimate peripheral participation affords an active means for learning, whereby knowledge is socially constructed within the normative practices of a CoP (Lave & Wenger, 1991).

Vygotsky's (1978) zone of proximal development (ZPD) offers a framework for how legitimate peripheral participation can be appropriately executed in the classroom, namely what a novice may progressively do within the CoP unaided by experts. Vygotsky outlines how students as novices experience crises at the junction between the zones of actual and proximal development, thereby requiring help from an expert, whether that is a more capable adult or peer, to resolve their intellectual or academic quandary. As students' progress from novices towards experts through the ZPD, the significance of individual achievements influence both learning and identity

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(Borthick, Jones, & Wakai, 2003). The progress within a CoP is a staple of constructivist learning environments (Beatrice, 2010). Therefore, this situative framework can visualize identity of both the individual and the collective, which may be useful to the current schema of K-12 schools where classrooms could function as CoPs for subject-area learning. Yet, despite decades of research, classroom instruction remains primarily didactic in nature, in which the culture and delivery of school science and mathematics directly impacts students entering these majors and careers (Aikenhead, 2006). In science, the nature of the curriculum itself has been termed inauthentic (Hodson, 1998), even downright dishonest (Aikenhead, 2006), not representing science as it is practiced among scientists (Stocklmayer, Rennie, & Gilbert, 2010). Mathematics curricula has failed to overcome similar challenges in illustrating and providing students the genuine CoP practices of mathematicians for decades (NRC, 1989, 2004, 2011). This asymmetry may stymie individual, much less collective, identity formation.

Classroom settings provide unique opportunities to develop multiple relationships between experts and novices. Enculturation into community-based practices may develop not only on an individual level, but also amongst and between group members. The evolving group participation, defined as "a group that derives from members' common interests, experiences and solidarity," is known as collective identity (Taylor & Whitter, 1992). Collaborative forces shape collective identity, which can be used as a cultural tool to bind members as they work together to accomplish shared goals of the community (Appiah, 2007). Collective identity formation is well described within multiple fields, like sports (Pelak, 2002), social movements (Choup, 2008; Fominaya, 2010) and politics (Greenhill, 2008; Wendt, 1994). However, research is needed on how collective identities are negotiated by students via their participation in a shared group within K-12 school settings. This identity plays a unique role in schools, through which students may write their internal narrative while they negotiate their roles within a CoP and accept the collective memories of others in the community (Appiah, 2014).

Accepting the view that individual identity is fluid (Gee, 2000) suggests classrooms may capitalize on this fluidity by fostering identities that strengthen the students' involvement in CoPs, helping them to negotiate multiple identities across academic disciplines over time. Encouraging identity formation in small groups can change individuals' attitudes and behavior through group interaction, making it a powerful pedagogical tool (Lewin, 1947; Thomas, McGarty, & Mavor, 2016). However, recent research by Idrus (2015) found "teachers were reluctant to relinquish their authority and power to students for various reasons which could be detrimental to the construction of shared identity" (p.28). This may stem from teachers' pedagogical practices shifting from a 'director' to that of a 'facilitator,' which is instrumental for CoPs to develop in classroom settings (Forbes & Skamp, 2014, 2016; Levitt, 2001). This suggests collective identity formation in classrooms deserves further exploration, particularly in disciplines like mathematics and sciences, where identity continues to play a key role in learning, persistence, and even the pursuit of advanced courses and long-term careers.

Collective Identity in Mathematics Classrooms

Mathematics is a subject that continues to receive unique attention in K-12 education, given its critical importance to the political and economic goals of global competitiveness (National Science Foundation [NSF], 2018). According to the National Science Board of Science & Engineering Statistics, high school students are woefully unprepared for college level mathematics and science coursework where underrepresented minority groups had lower benchmark scores. For example, benchmark scores reveal drastic differences between Hispanic and African-American students (27% and 13%, respectively) and their White and Asian-American peers (50% and70%, respectively) (NSF, 2018). Moreover, historically and presently, the community of mathematicians remains homogenous; evidenced by the low percentage of women and non-Asian minorities who pursue STEM degrees at US universities (NSF, 2018). Similar results from high school seniors who pass the National Senior Certificate examination in South Africa (Adler & Sfard, 2017) reveal that the pervasiveness of gender and racial/ethnic inequity among those who become eligible for entry into later tertiary STEM education and the workplace is not solely limited to the US culture. Factors such as parental socioeconomic status, language of instruction, and rural home environments draw further attention to the systematic disparity in educational outcomes faced by marginalized learners across cultures (Adler & Villay, 2017). Subgroup results from the Grade 9 Trends in Mathematics and Science Study (TIMSS) 2015 study support findings by Adler and Villay (2017), as well as reveal little change in mathematics achievement trends by gender (Mullis, Martin, Foy, & Hooper, 2016). These low numbers raise concerns among educators and mathematics professionals about the traditional classroom ethos that continues to prevail for subjects like mathematics (Kilpatrick, Swafford, & Findell, 2001). The societal consequences are evident. The NSF (2018)

ISSN 2474-7432
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has indicated that reduced participation of underrepresented minorities facilitates a lack of diversity in the workplace. Other researchers have found that productivity and innovation in science and engineering spaces are negatively impacted (Hewlett, Marshall, & Sherbin, 2013; Ellison & Mullin, 2014).

An examination of school and classroom instruction structures reveal that students' experiences over time impact their views of mathematics and inform their mathematical identities. In traditional classroom structures, "children become socialized by school and society, they begin to view mathematics as a rigid system of externally dictated rules governed by standards of accuracy, speed and memory" (NRC, 1989, p. 43). Research from multiple developed countries revealed that elementary and secondary mathematics students share a poor, inaccurate view of the field (Picker & Berry, 2006; Rock & Shaw, 2000). Results from Rock and Shaw's (2000) Draw a Mathematician Test suggested that young children tended to think mathematicians did the same kind of mathematics they did in the classroom, with virtually all young children picturing mathematicians in classroom-like scenes. Picker and Berry (2006) found that middle-school students depicted similar images. Overall, younger children depicted mathematicians smiling. However, by middle school, these views changed. Approximately 23% of middle school respondents shared that "mathematicians did 'hard' and 'complicated' problems, as well as 'problems that no one else could solve'" (Rock & Shaw, 2000, p. 553). Similar negative trends in gender equity and knowledge about the field were evident as children aged. More than half of kindergarteners depicted more women than men, while second- through fourth-graders depicted an approximately equal number of women and men, often working collaboratively in real-world settings (Rock & Shaw, 2000). Yet, both male and female middle-school respondents depicted more males (93.8% and 61%, respectively) (Picker & Berry, 2006).

Both studies by Rock and Shaw (2000) as well as Picker and Berry (2006) concluded that students view mathematicians as doing hard work that no one wanted to do; they lacked a clear understanding of what mathematicians do in the real world. Picker and Berry found additional negative views of mathematics held by middle school students, such as a sense of power imbalance and mathematics as absolute knowledge held by authoritative adults. These recursive patterns reveal that the mathematics community comprised of teachers, other students and other outside influences is subtly shaping the shared identity of mathematics students are developing. These findings are particularly damaging for minority or underrepresented students, who lack experiences with authentic disciplinary practices; research suggests it is unlikely these novice learners will adopt the goals to be successful in defining themselves within the practice or embarking in the development of robust mathematical identities (Boaler, 2002; Nasir, 2002). Mathematics was viewed as a subject for those who have a certain innate ability and students often felt incompetent if they could not process the material with ease and speed, especially when teachers made it look effortless (Picker & Berry, 2006). This suggests that traditional classrooms, presented mathematics as a natural identity instead of as a CoP discussing the challenges that are naturally part of the thinking process. Additionally, teachers were largely unaware of students' stereotypical views and lack of knowledge about the field, as well as their own role in shaping and altering students' views; overall resulting in students lacking a sense of belonging to the group, relevancy to their lives, and encouragement to pursue mathematics fields (Picker & Berry, 2006). Later educational experiences may perpetuate these views. A recent poll of scholars across various disciplines at American universities revealed that academics in mathematics were the most extreme of the STEM fields in terms of emphasizing fixed, innate ability (Leslie, Cimpian, Meyer, & Freeland, 2015).

Mathematics remains a subject towards which students have strong feelings. Yet, the observed differences do not align with capability, but rather with learning practices (Boaler & Greeno, 2000). Most students receiving didactic instruction rejected mathematics overwhelmingly because the practices in which they participated were incompatible with developing situated mathematics identities (Boaler & Greeno, 2000), which are defined and based upon shared interest (Wenger, 2011) and belonging (Handley et al., 2006). Many of these students viewed traditional mathematics classrooms as requiring them to be passive recipients of knowledge, which they came to accept as part of the normative classroom behaviors. These same students, all of whom were successful mathematics students, perceived other subjects as requiring thought and creativity, affording them opportunities for expression and agency. However, opposite views of mathematics as a subject valuing connected understanding and opportunities to express thinking were held by students who received discussion-based mathematics instruction (Boaler & Greeno, 2000), which suggests that CoP classroom settings mediated the formation of these views. Their results suggest that abstract, decontextualized instruction is more alienating for girls and non-Westerners than boys and Western students. Even more concerning is that these findings by Boaler & Greeno (2000) substantiate concerns that systematic marginalization of select groups from a subject at which they show promise exists.

Collective Identity in Science Classrooms

The National Center for Science and Engineering Statistics found that the percentage of women who participate in science and engineering careers increased due to their roles into various health care industries (as nurses, dietitians, physician assistants, health technologists and technicians to name a few) but that their numbers in all science and engineering fields remains stagnant overall (NSF, 2018). Current data reveals that the majority of scientists and engineers in the United States are non-Hispanic Whites, followed by Asians and Asian-Americans (67%, 21%, respectively) (NSF, 2018). Hispanics, African-Americans, and American-Indian or Alaska Natives have low levels of participation (6%, 5%, and 0.2% respectively) compared to their U.S. residential population (NSF, 2018). A similar examination of the science and mathematics teacher workforce suggests most teachers are disproportionately White (Sleeter, La Vonne, & Kumashiro, 2014), despite lacking certification and years of teaching experience at schools that serve minority and high-poverty students (NSF, 2018). These statistics portray challenges science educators face to engage and sustain students from all backgrounds, which is has been credited to the science identity gap (Tan, Calabrese Barton, Kang, & O'Neill, 2013). Identity is a critical construct, omnipresent when students are partaking in science activities, regardless of it being intentionally incorporated into science instruction (Calabrese Barton, Kang, Tan, O'Neill & Brecklin, 2013). Tan et al. (2013) theorized that the science classroom can be an incubator for fostering and developing science identity. They argued that the science classroom can be viewed as a CoP in which students continuously co-construct their evolving identities as they engage in shared tasks with their classroom peers if the teacher creates classroom norms to develop and support emergent science identities (Tan et al., 2013). These authors dissected the experiences of young women and viewed classrooms that presented various narratives and histories of what it meant to be scientific, encouraged students to be curious, excited, and an active participant in learning and doing science. Numerous other scholars exploring identity have identified empirical connections between the critical importance of constructing a robust science identity (e.g. seeing oneself that can and does do science) to science interest and learning in all school age groups including young children (Archer, Dewitt, Osborne, Dillon, Willis, & Wong, 2010; Maltese & Tai, 2008), females (Brickhouse, Lowery, & Schultz, 2000; Fordham, 1996) and students of color (Nasir & Saxe, 2003). The literature has also established numerous connections between identity and STEM persistence for underrepresented groups through college and career (Brown, 2002; Carlone & Johnson, 2007; Espinosa, 2011; Johnson et al., 2011).

When considering identity, science education should be wary of the implications of an unfettered inclusion of value-based character education in which students evaluate the ethical issues science presents in society. This may introduce the misconception that scientists individually develop personal or opinion-based judgments on large bodies of knowledge as a whole, versus a careful and intentional group negotiation (e.g. reproducibility, peer review) that occurs within a CoP. This may also play a role in addressing the psychological and physical stereotypes of the typical scientist (Mead & Metraux, 1957). As Picker and Berry (2006) suggested for mathematics, the power imbalance that similarly exists in science classrooms needs to shift, so that students are presented with accurate images of mathematics and scientists that not only better conform to reality, but also more palatable for adoption within their own identities.

The future challenge for education is incorporating sustained ways of thinking about authentic problems and practices. Without such an intervention, individual and collective identities may be superficial and short-lived. New community members should be initiated into legitimate ways of thinking that mirror authentic practices within the field, meaning young children should be participating in developmentally appropriate and legitimate activities in classroom CoPs modeled from STEM-based CoPs. Therefore, the K-12 classroom setting holds incredible power in how to negotiate norms and practices, as well as how new knowledge is negotiated and legitimized by the community of its practitioners (Hodson, 2009). However, it is arguable that this element of instruction has serious consequences. Asymmetries between the classroom STEM-centered CoP and that of the actual STEM CoP will reinforce negative stereotypes of how science and mathematics are done by experts, reducing any shared interest or affinity (identity) to those CoPs. Until this is systemically remedied, educators and policymakers will continue to face challenges in sustaining the STEM pipeline, which include the social impacts that are derived from a skewed scientific worldview.

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Recommendations for Fostering Collective Identity in the K-12 Mathematics and Science Classrooms

Research indicates that in both mathematics and science, mindful educators can mitigate inequity and social stereotyping of classrooms. For example, Burton (1996) found that science teachers typically cued, prompted, and questioned boys more often than girls. In another study, known as the Computer Equity Expert Project, Sanders (1996) attempted to combat teachers' views regarding gender inequity. After teacher training, greater teacher awareness and perceptual changes around gender inequity occurred, as did subsequent differences within teachers' classroom practices. Some of the changes Sanders observed included providing girls with equal access to computers, incorporating explicit use of positive female role models during instruction, and calling on both genders equally during classroom discussions. Sanders proposed that larger, systematic changes would require greater training on the part of many more stakeholders within the school community. Reis (1998) similarly concluded that one reason some girls fail in mathematics is due to stereotypical perceptions they encounter in school and life, namely that they are simply not expected to succeed in mathematics and sciences. Teachers even attributed success differently for females; they viewed success as due to ability in males, while due to effort in females (Reis, 1998). Such research supports a widespread call for change in classroom structure through widespread initial and continuing professional development, so that all students develop a sense of belonging to the community and a more accurate collective view of mathematics and related disciplines.

More recent research reveals the related benefits of incorporating a growth mindset approach, or infusing concepts of goal setting and motivation to develop one's intellectual achievement over time (Blackwell, Trzesniewski, & Dweck, 2007). Teachers play a role in developing students' growth-oriented mindsets in schools through classroom-based interventions (Yeager & Dweck, 2012). In mathematics instruction, this manifests as helping students learn, understand, and appreciate mathematics concepts (Boaler, 2016; Paunesku, Yeager, Romero, & Walton, 2012). For example, one empirical study found mindset interventions positively changed classroom motivation and significantly reversed mathematics achievement declines for low-achieving middle school students within the same year, whereas their fellow classmates in the control group continued to decline academically (Blackwell et al., 2007). Dweck claimed that her research shows "that a fixed mindset contributes to this eroding sense of belonging, whereas a growth mindset protects women's belief that they are full and accepted members of the math community" (2008, p. 5), drawing a direct line between growth mindsets as a strategy to foster math-based CoPs and consequentially empirically linked concepts of identity and identity formation (Eckert, 2006; Goos & Bennison, 2008; Wenger, 1998, 2011).

Dweck (2008) describes that growth mindsets have affordances in also boosting science achievement and developing students' senses of science belonging. In addition, other instructional practices in contemporary classrooms have also successfully fostered science identity, and as an extension, collective identity. Hodson (2009) noted the use of case studies as "an effective way to bridge the 'gap' between the two cultures of arts and sciences…ensuring that future politicians and business leaders have some basic understanding of science, scientists, scientific practices and scientific developments" (p. 328). This aforementioned case study approach is defined as providing historical or current vignettes of scientists engaged in their CoP to address a specific societal problem or issue. Data, evidence, and observations, collected from experts in the field, guide students through the history of the individual cases. Hence, students vicariously participate in the successes and challenges that the scientist experiences to mimic the reality of scientific endeavor. Research suggests case studies for adolescent science learners be an "antidote to the excessive realism and determinism typical of many pupils…their image of the certainty of scientific knowledge is challenged…[and] the uncertainty of a scientific theory does not necessarily nullify its usefulness in making further progress possible" (Irwin, 2000, p.5). Additionally, Hodson acknowledged that this approach may be especially effective in even younger children as stories capture the social, cultural, and affective aspects of the discipline. Not only does this provide a rich and robust context for understanding complex scientific issues in situ, but also serves to stem issues in the "criticizing of scientists" that occurs when students resort to a "'villains and heroes' approach to scientific history" due to a lack of chronological appreciation that is derived by an understanding of science situated within time and history (Hodson, 2009, p. 329). Hodson further criticized that "scientists are portrayed as somehow free from human foibles, humor, or any interests other than their work" in which students may align their personal experiences or perceived shortcoming understanding content to that of authentic scientists and the scientific process (p.343), but by incorporating a strong contextual basis of scientific processes and inquiry, as well as leveraging original field notes, source materials and other primary

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resources (National Center for Case Study Teaching in Science, 2019), science educators can address such issues.

The introduction of scientific argumentation to the science classroom setting has been another successful strategy for promoting scientific literacy and inquiry and challenging students to make evidence-backed claims that withstand the community standard of peer scrutiny (Erduran & Jimenez-Aleixandre, 2007). Teachers serve as experts, who moderate and model this type of argumentation-based discussion for students, as these novices develop expertise through authentic and genuine community practices. Apprenticeship-based experiences, like argumentation, aid individual students in the adoption of a scientific identity (Polman & Miller, 2010). Moreover, teachers who cultivate classroom settings with robust peer interaction (e.g. whole- and small-group argumentation) may provide legitimate opportunities for collective peripheral participation by leveraging the authentic activity of the CoP of real scientists. Therefore, argumentation is a useful strategy as, "learning science involves both personal and social processes…On the social plane the process involves being introduced to the concepts, symbols, and conventions of the scientific community" (Driver, Asoko, Leach, Mortimer & Scott, 1994, p. 8). With opportunities for argumentation (a vetted and authentic science practice), students within a classroom CoP may foster a robust collective science identity. Developing teachers' mindsets to curate a classroom CoP requires sustained periods of time, as teachers' and students' views of science shift (Driver et al., 1994; Opfer & Pedder, 2011). Therefore, more research is needed on classroom-based scientific argumentation to fully understand its nuanced benefits for students.

Understanding the larger endeavor of scientific pursuit known as the Nature of Science (NOS), or the "values and assumptions inherent to the development of scientific knowledge" arguably affords students opportunities to develop a more accurate collective science identity (Lederman, 1992, p. 331). Numerous studies have sought to understand how teachers instruct students in the NOS (see Abd-El-Khalick & Lederman, 2000) and assess how students interpret the NOS (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). To aid teachers in NOS-grounded instruction, pedagogical recommendations by Lederman, Antink, and Bartos (2014) are to provide students opportunities to engage in scientific inquiry, so they may understand "scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), subjective, necessarily involves human inference, imagination, and creativity (involves the invention of explanations), and is socially and culturally embedded" (p. 287). Instruction grounded in the NOS has additional positive outcomes, through providing a more realistic picture of science CoP may help to remediate students' negative stereotypes of scientists and scientific endeavor (Bodzin & Gehringer, 2001; Lederman, Wade, & Bell, 1998). In sum, case studies and argumentation are two, of many, classroom-based strategies to aid students to engage in the practices of scientists as they occur within the scientific CoPs.

This leads to the most salient point, the most important aspect for a teacher to cultivate collective identify for his or her students is to foster a CoP through building a classroom community. As the teacher creates his or her own science community, characterized by shared discursive practices (Lemke, 1990), students are communally engaging in cultural apprenticeships within the classroom-based and content-centered CoP (Driver et al., 1994). Research indicates that the cultivation of a classroom community is the superstructure to effectively coordinate science students, materials, tasks and science concepts (Harris & Rooks, 2010). Hence, identity formation extends beyond the science classroom to mathematics and other related STEM fields, but the research suggests explicit instruction with level-appropriate scaffolds that are gradually removed to appropriate the cultural norms of a scientific CoP and rely upon a group consensus are critical factors.

Discussion

Given that learning and identity formation is an ever-evolving process, legitimate peripheral participation should exemplify the desired cultural practices. The emphasis should be on the value of verbal discourse as a process of learning a deeper sense of value of community and becoming part of the community for novices (Lave & Wenger, 1991). Also, this process should be sustained over time; as it requires incremental improvements for teachers and students to alter the current image of STEM professionals based on school instructions to one that more closely resembles their respective CoP. Recommended changes shared here have been utilized by many teachers for decades, but in-depth studies are needed to better understand and advocate for widespread change. First, the roles of teacher and learner require redefining, so that the environment is open and supportive of all students and the focus remains on the nature of inquiry (Reis, 1998). This notion is well established in the research field, yet can be challenging to replicate in the classroom. To this end, classroom teachers and their supporters continue

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to advocate for themselves to no longer be viewed as the sole authority figure, or simply a body of "objective" knowledge, but rather a distributer of intelligence centrally revolving around "relationships" and students learn through developing "a community of voices" that authority resides within the individuals and collectively within in the mathematics community (Burton, 1996, p. 142).

Children who perceive STEM skills as useful and necessary for future careers are more likely to enroll in optional and advanced, related courses (Hart & Walker, 1993; Picker & Berry, 2006) or select STEM careers for financial independence or empowerment (Stoet & Geary, 2018). This underscores the importance of this early and shared (STEM) interest Wenger (2011) ascribes to STEM identity formation. Students' attitudes towards various disciplines can be further improved when teachers show enjoyment and engage students through discovery lessons and use of concrete models, as well as show its utility in everyday life and application in future careers (Hart & Walker, 1993; Renga & Dalla, 1993). As teachers engage students in the content, they are actively fostering the sense of belonging Handley et al. (2006) ascribed to being important components of CoP-based collective identity. Furthermore, students who take advanced mathematics courses, in which they learn to work, think, and reason logically, are more productive later in their jobs (Rose & Betts, 2004). Teachers should also utilize explicit hands-on collaborative experimentation as is typical of the real world, avoid sex-stereotyped examples, not allow boys to dominate legitimate peripheral participation, furnish career information, provide more encouragement for girls and other less confident students, and use discourse-based instruction surrounding problem-solving practices that promote the creativity and depth of thinking that mirrors later working environments, so more students can develop realistic identities (Boaler & Greeno, 2000; Hart & Walker, 1993; Reis, 1998).

Students require more opportunities to struggle with appropriately difficult problems over time, as afforded through ZPD, to learn persistence and that problems require time, effort and even failure. When students were asked for reasons when they felt a sense of belonging in learning activities, they stated that they preferred curricular material with depth and relevance that came from real-world sources, differentiated level of challenge and pacing and having some choice in their development of own expertise (Hart & Walker, 1993). These same students also stated that motivating teachers were "supportive, caring, understanding, sharing mutual trust and respect, listening to and respecting diverse opinions, offering choices, explaining things, not telling all the answers, being fun, humorous and enthusiastic, sharing interests, holding high expectations, giving feedback, and being accessible" (Hart & Walker, 1993, p. 28). In addition to changes in instruction approaches, effort is needed so that assessments align with instruction. They should encompass a wide range of open-ended strategies with clear criteria, allow students to reflect on learning, recognize complexity and identify a range of problems (Gipps, 1996). Large-scale implementation of these various reform-oriented classroom components may help alter more students' perceptions of mathematics and science, and therefore, create more realistic and therefore facilitate the development of robust collective identities through developing shared interest through authentic activity warranted for identity development (Wenger, 2011) of both domains.

Conclusion

The cultural goal of the CoP was essentially summarized by Gipps (1996) when she said,

> we need to talk of not a pedagogy, for girls and boys, but pedagogy being composed of a range of strategies (which include a range of materials and content, teaching styles, and classroom arrangements/rules) for different groups of pupils and for different subject areas. (p. 265)

This shift affords all learners an opportunity to reconstruct their approach to learning, and thus for practitioners, careful planning is essential for successful implementation of these changes. This includes consideration of students' interests, establishing obtainable goals and adjusting the difficult level of tasks to the background and cognitive developmental level of students, thereby simultaneously building confidence and motivation to learn and understand (Renga & Dalla, 1993). To accomplish this feat requires a critical component, which are research-based strategies for teachers, so they may provide legitimate opportunities for participation and proper scaffolding that is not only developmentally appropriate for content but also develops the mental acuity for their students. It should be noted that this process takes time and administrative support, especially given no one prescribed system of rules will fit all different groups of students or subjects every year. Yet, incremental alterations must be made by mathematics and science educators to benefit all members within the community and alter a shared view of a collective identity that reflects the authenticity of STEM disciplines.

We are still far from reaching these desired goals on a large scale, despite decades of research on how to implement practices valued by the mathematics

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and science communities. Only if all members feel a sense of belonging and become legitimate participants within the CoP can we ensure more students make an informed choice about inclusion or exclusion from the group regarding their future careers rather than solely based on access or denial to resources. Inclusion of more students benefits the entire community and aids in field advancement to achieve the mission of an inclusive and engaged STEM pipeline. Therefore, both researchers and practitioners hold mutual accountability to ensure that students' collective identities are forged in K-12 classrooms that are reflective of STEM's practices and reflect the learners' unique contributions to STEM. Such classrooms will lead to students feeling engaged in science and mathematics coursework, and empowered to pursue science and mathematics in school, college, and career.

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Acknowledgment

The authors would like to gratefully acknowledge K. Natasha Elliott for contributing ideas to the manuscript and the late NCSU Assistant Professor, Dr. Jimmy Scherrer (1978-2015) for his technical assistance and valuable insight to the undertaking of this project.

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KENAN FELLOWS PROGRAM
FOR TEACHER LEADERSHIP

Journal of Interdisciplinary Teacher Leadership

ISSN 2474-7432

2019, Vol. 4, No. 1

A Case Study Approach to STEM Supervision: A Collaborative Model for Teaching and Principal Preparation

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ABSTRACT

School principals are responsible for supervising STEM teachers, yet many principals did not teach in the STEM fields and have limited training in STEM content, process and practice. This presents a challenge for principals when they observe STEM classrooms and provide feedback to teachers. In this paper the authors describe a study about principals' views of STEM classrooms and the observational feedback principals provide to those teachers. The results of the study suggest principals need a deeper understanding of reform minded STEM process and practice, and alternative approaches to providing teachers with observational feedback. Building on the results of the study, the authors present a collaborative model (Innovating Teaching and Learning Leadership (iTALL)) for preparing pre-service principals and pre-service STEM teachers and describes training in the STEM process and practice. Observational exercises are discussed and changes in observational protocols when conducting classroom walk-throughs are described.

Key Words: *Instructional Leadership; Principal Education; Supervision; STEM Process and Practice*

Introduction

Principals are responsible for promoting school improvement (DuFour & Fullan, 2013; Glickman et al, 2013; Matthews & Crow, 2010; Duke, Carr, & Sterrett, 2013) and have a fundamental role as instructional leaders in schools (Hallinger & Murphy, 1987; Leithwood, 1992; Matthews & Crow, 2010; Waters, Marzano, & McNulty, 2003; Sterrett, 2011). Furthermore, student achievement is affected, at least indirectly, by the principal's leadership (Bambrick-Santoyo, 2012; Cotton, 2003). Principals have the complex task of working with teachers at numerous grade levels and subject areas, yet there is limited research about how secondary-level administrators address content-specific instruction (Lochmiller, 2016). One way in which principals work with teachers is through supervision of classroom instruction. Given the recent significance placed on science, technology, engineering, and mathematics (STEM) instruction promoting student literacy and success, reports have cited an urgent need for improving both the quality and the size of the STEM teacher workforce in the United States (National Research Council, 2011; National Science Board, 2007). The role of principal as instructional leader of STEM instruction is critical. Unfortunately, many principals have not had formal training, teaching experience, or professional development in the STEM areas (Sterrett, Rhodes, Kubasko & Fischetti, 2018). We provide more details about supervision and the STEM process and practice in the following sections.

Supervision and Walk-throughs

Sullivan and Glanz (2013) describe supervision as "the process of engaging teachers in instructional dialogue for the purpose of improving teaching and increasing student achievement." (p. 4). Principals need to be more collaborative and assist teachers with reflection on instructional practice (Sullivan & Glanz, 2013). One instructional leadership strategy to address the above mentioned need is for principals to conduct walk-throughs with teachers. Walk-throughs are short, non-evaluative, and focused observations to provide feedback to teachers (Kachur, Stout, & Edwards, 2013; Zepeda, 2009). However, not all walk-throughs affect student learning (Moss & Brookhart, 2015). Traditional walk-throughs are evaluative and the principal may attempt to "fix" defective teaching practices (Sullivan & Glanz, 2013). The traditional view on walk-throughs is less effective. For student achievement to rise, principals need to frame walkthroughs as a learning process for themselves, provide effective feedback, and promote professional growth (Grissom, Loeb, & Masters, 2013). Principals may, or may not, have received some training on how to conduct walk-throughs. Given that they are coming from a variety of teaching backgrounds, they may notice different aspects of STEM classroom instruction or have varied interpretations (Sterrett, Rhodes, Kubasko & Fischetti, 2018). As a result, it might be reasonable to infer that the messages they convey to teachers about STEM processes and practices are of an inconsistent nature.

STEM Content and STEM Process and Practices

Integrated STEM reforms in education serve to reduce the traditional barriers that separate the four disciplines while promoting the intersection of content-area instruction leading to interdisciplinary solutions to existing real-world problems (Breiner, Johnson, Harkness, & Koehler, 2012; NGSS Lead States, 2013). Furthermore, the shift in STEM education "is not about the subject but about the learning process of inquiry, imagination, questioning, problem solving, creativity, invention, and collaboration" (Myers & Berkowicz, 2015, p. 8). It is unrealistic to expect principals to be experts in all content areas. However, without a deep understanding of STEM teaching and learning, school-level leaders and principals may find it difficult to evaluate and support teachers' efforts to meet the needs of STEM students (Glickman, Gordon, & Ross-Gordon, 2010).

While we can't realistically expect all principals to have an in-depth knowledge of STEM content, it is important for them to understand some of the critical components of the STEM processes and practices. According to survey data collected by Breiner, Harkness, Johnson and Koehler (2012), it was concluded that even STEM professionals are confused as to what STEM means. This presents some challenges for effective observational feedback leading to the teacher growth we expect to see in STEM-infused classrooms. Teachers receive general pedagogical guidance and support from their administrators, thus, we assert that effective professional development for principals helps them understand some common STEM instructional processes and practices that will lead to improved feedback for teachers.

Research Questions

Given the lack of or limited STEM instruction training for principals, it is vital to consider how they view STEM instruction and investigate potential ways that preparation programs can provide STEM training within the university program. In this paper we describe a study about principals' views of STEM classrooms as well as propose a collaborative model for change. We answer the following two research questions:

1. What are principals' views of STEM classrooms?
2. What feedback do principals provide to STEM teachers after observing their classroom?

Based on the results, we share a collaborative model designed to serve both our principal- and teacher-preparation programs.

Principals' Views of STEM Classrooms and Feedback

Methodology

In this study we investigated how four middle grades principals across one county viewed STEM classrooms. The study was funded by a university award, the Charles L. Cahill Grant for Faculty Scholarship, at the University of North Carolina Wilmington. We employed a semi-structured interview and asked multiple questions about STEM classrooms and the feedback principals would provide to the teachers. For consistency purposes, one researcher conducted all the interviews, and recorded and transcribed the conversations for accuracy. Two researchers separately coded participant responses and assigned meaning. Both researchers collaborated to qualify any emergent themes generated across the codes. Emergent themes were placed in context and highlighted from each of the respondents. All interview responses, codes and emergent themes were collected in a Microsoft Excel spreadsheet. Researchers discussed and debated the emergent themes for accurate identification, importance and application. Patterns within and across respondents were recorded.

Results

As noted in Table 1, the four principals had different teaching backgrounds and experiences. Principal A had worked as a school counselor for three years prior to becoming a school administrator. The other three principals had taught in public schools for at least 12 years; Principal B was a middle school mathematics teacher, Principal C was a high school science teacher, and Principal D was a middle school teacher. All three participants taught core subject areas (math, science, social studies, and language arts), and two of them taught a field within STEM.

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Table 1 *Middle School Principals'Teaching and Leadership Experience*

Name (anonymized)	Years of teaching experience	Subject area teaching experience	Years total as school administrator (including assistant principal	Years as principal
Principal A	3	Middle School Counselor	11	9
Principal B	12	Middle Grades Math	10	7
Principal C	15	High School Science	10	4
Principal D	12	Middle Grades Math, Science, Language Arts, and Social Studies	11	7

In terms of teaching styles, all four principals considered themselves student-centered, using terms such as "workshop style," "hands-on," "inquiry-based," and "engaging." Only one participant described whole-group instruction as being meaningful; the other three tended to focus on phrases such as "PBL," "hands-on and relevant" and "workshop" when discussing what sort of instruction, they hoped to see in the classroom.

Principals' views. All four principals were asked what they hope to see when observing a STEM classroom. While the principals' responses varied when answering the question, there were two common themes that emerged from the interview data. The first theme to emerge was that all principals were expecting to observe engaging hands-on activities in the teacher's classroom reflecting STEM teaching processes familiar to them. Principal A was clear in her assertion that she hoped to see "engagement, higher-order thinking skills, and problem-solving, inquisitive learning, inquiry-based." She also recognized that STEM-infused classrooms can sometime seem chaotic to the outside observer, but principals need to look deeply at the variety of activities happening, sometimes simultaneously. When discussing the need for teachers to be engaging, Principal B said, "my desire for that is to be as hands-on as we can make it." He acknowledged that there may be external influences to consider, "let me say I definitely think the push is to make their classes more engaging, more hands-on," Principal C stated that "I want to see them actively learning, they shouldn't just be sitting and getting. Everybody should be experimenting or working on their engine or doing the flight simulation…" Lastly, Principal D referenced an interest to observe technology integration in the class. She stated, "During that time we try to bring in some STEM activities that the students can use that are necessary with a laptop and things like that, but just with the idea of being creative and building things with your own hands." Principal D consistently referenced technology integration as a function of STEM.

The second and extremely interesting theme is the perceived obstacles and barriers faced by both middle school STEM-infused teachers and the principals that observe their classrooms. STEM content understanding seems to be one of the consistent challenges for the principals. For instance, Principal A states:

> [In] the STEM class, if you didn't know what you were going in and looking for, it might look chaotic, because at any one time there's 10 modules that the students are working on so these two kids might be building a rocket, and these two might have a saw out and actually doing construction, and these kids over here are doing landscape design or architecture, so you have to understand what you are going in and seeing.

She asserts that principal observers need to take into consideration a preconceived STEM context necessary for effective observations. Principal C further supports that assertion when she states that "I expect there to be chatter and motion, when I go in there, very different than when I walk into a regular math classroom." Principal B acknowledges that time is a barrier to integration and states "I think that teachers, I don't know that we set teachers up to be successful in a normal 60-minute class period to be great STEM teachers." He continues to say "the whole understanding of content doesn't just come overnight. Like the depth of understanding, so there's work that has to be done with new teachers where they may make their shifts more easily, their content knowledge is less." Content knowledge in science and mathematics, or lack thereof, is another challenge recognized by Principal B, especially for new middle school teachers. Lastly, Principal D alludes to there being different STEM expectations for different teachers as they navigate the idea of 'flex grouping'. She continues to say "within that flex grouping we have three levels, one of them is an enrichment level" where the expectation is that technology is infused throughout the classroom. This is not the case in the general or applied levels where there are "STEM activities the students can use that are necessarily with a laptop and things like that, but just with the idea of being creative and building things with your own hands. But not necessarily the technical piece." It seems that this principal is prepared to observe classroom teachers with different STEM expectations based upon student grouping. It is important to note that these responses all materialized in the context of the original question.

Principals' feedback to teachers. Principals were asked to reflect on their feedback to teachers after an observation. The focus of the interview feedback, as to be somewhat expected, primarily emphasizes student engagement in the classroom. But, a distinct and common theme to emerge is that the middle school principals interviewed make no mention of providing feedback about STEM content or process. Principal A has very clear questions as to what she wants addressed during her teacher observations. She commented in the interview, "I think [the feedback] would be exactly the same. Are students actively engaged? [The students typically work in pairs]… so is one student sitting and letting the other student do all the work? Is there shared ownership of the projects that they're working on? Are they actively engaged? Are they adhering to the expectation[s] of the classroom?" She makes an assumption that a STEM classroom only requires there to be group work around projects that are collaborative in nature. Principal B was similar in that the feedback is primarily about student engagement and interactions. He stated, "Well, I would provide specific feedback for the type of lesson it is. I don't know that I want to go into a class and say this is a science-math class so I'm going to give this type of feedback. The content to me doesn't dictate the feedback. Of course, content knowledge is something that is important, but what are the students doing when you're observing?" It is interesting that he addresses teacher content knowledge and practice as being important but not at all the focus of the feedback. Again, Principal C's feedback reflected a focus on the kids and their engagement with the lesson. She said, "I like to go back to the teacher and we sit down and talk about where the kids really engaged? Could they talk to me about what they were doing? Or were they just kind of going through the motions." Student engagement is paramount to feedback about STEM learning. Lastly, Principal D's feedback to teachers is about creativity and out of the box thinking. She states "When it comes to STEM…I don't necessarily feel like we need to be always looking at them with the assignment of a grade because really the piece of this is that they can be as creative and far-reaching in their thinking as they can be." It is clear from the interviews that student engagement is a primary focus for these middle school principals. What is missing from the principal feedback provided to teachers are conversations about STEM content knowledge or applicable teaching processes and practices.

When providing feedback to teachers, principals were asked to identify the challenges they face when observing STEM classrooms. Three principals expressed challenges of familiarity and understanding of STEM content, while two of the principals articulated issues of STEM process. Principal A was honest about her lack of content knowledge in the discipline and its impact on providing teachers feedback. She stated, "So, I don't always have the content knowledge, so that is hard for me." She elaborated later in the response saying, "That's the biggest struggle; it's impossible to be the expert in all disciplines at all grade levels, and so I think you have to just rely on what you know works and what learning should look like, to know that it's going to turn

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out okay." Principal B didn't feel limited by the content when providing feedback to his STEM teachers. He said, "There are certain behaviors that are appropriate across content, certain levels of engagement, certain levels of rigor that you look for. And so I do think there's a lot of crossover." This could be due to his background in middle school mathematics. He went on to say that his challenges are more a product of process, saying, "My challenges specifically to STEM teachers, though, is helping them see more best practices, so if I wanted to say one thing that's a challenge for developing STEM teachers at…middle school…it is letting them see better examples of excellence." Principal C quickly highlighted the learning process as being her biggest challenge when answering the question. She stated, "I think the challenge is that they're all doing something different and so it's not your typical instruction." With a background in science education, Principal C finds the style of active classroom led by her STEM teachers difficult to measure. She goes on to say that there are challenges with assessing STEM content and understanding. "I've got the math standards and I've got the science standards and I understand it, but [the issue is] for me as far as making sure they understand it." Principal D also has some concerns about challenges in providing feedback about the STEM content. She is quick to question her ability in "understanding the technology myself…Now the math is not an issue, although it's been a long time."

Discussion related to STEM process and practice. Observing and understanding STEM process and practice in a classroom does maintain some similar characteristics to good pedagogical process and practice. Myers and Berkowicz (2015) argue that we should expect to see an environment that empowers students to be active, engaged, innovative and creative. The interview data suggests that all four principals have at the very least a cursory understanding of STEM process and practice consistent with reform minded pedagogical strategies. For instance, Principals A and D, while both limited in their understanding of STEM content, recognize that STEM-infused classrooms require a high degree of creativity and active learning for students to be successful. Principal A even employs terms such as "inquiry", "problem-based learning" and "collaboration". Consistent with reform-minded strategies, Principal D argues that technology integration is critical for student learning in STEM (Bybee, 2013). One would expect that based upon Principals B and C's STEM backgrounds, an understanding of STEM process and practice in the middle school classroom shouldn't be foreign. And the data suggests that it wasn't. The idea that STEM requires active learning leads Principal B to assert that time is a consideration for teachers and students. STEM teachers have argued that time is always a limiting factor in their success with engaging students in activities and exercises consistent with addressing pedagogical strategies such as problem-based learning. Principal C expects to see students engaged in "experiments" and "doing" in class. Active learning is consistent with effective STEM-infused classrooms.

Conversely, the interview data informs us about the principal's depth of understanding of STEM process and practice. In many ways, all four principals exhibited limited views, and this reality creates some questions to consider. Principal A was extremely honest in her challenges providing feedback to STEM-infused teachers. She relied on the familiar and traditional pedagogical strategies to guide reflective feedback to her teachers. Student engagement, while symptomatic to good teaching, isn't necessarily a STEM process or practice. If principals observe student engagement in a STEM-infused class, should the observing principal be satisfied with the teaching? If so, are there any recommendations being offered to the practicing teacher for changes or adjustments in process or practice specific to STEM? Additionally, principals make no mention of the interdisciplinary nature or crosscutting concepts foundational to STEM education reforms (Bybee, 2013). Principal B consistently talks about the similarities and differences between "math" and "science" content classes. Content knowledge is important. But is there any observational expectation that STEM teachers work across their disciplines in an integrated fashion? Principal C contrasts her expectations for observing and providing feedback for an "active" STEM class with her expectations for a "regular math class". Should regular or on-level education classes be expected to have active learning consistent with STEM process and practice? Should there be a difference in approach? Or are those strategies reserved for specific populations of students only? Principal D alludes to the notion that expectations

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for observing STEM activities should be different for different groups of students, especially as is it relates to technology integration. Again, STEM content, process, and practices for all students is emphasized throughout the literature (NGSS Lead States, 2013). Most principals would probably agree that STEM process and practices are important for their teachers active in the interdisciplinary domain. But, there appears to be real observational challenges inherent in the feedback from principals and administrators.

The Innovating Teaching and Learning Leadership (ITaLL) Model

Some principal preparation programs do not align with principals' real jobs (Wallace Foundation, 2016). In schools, principals and teachers collaborate in various capacities, yet in preparation programs principals and teachers are trained separately. Rarely do pre-service principals and pre-service teachers interact with one another in any meaningful way. In the Innovating Teaching and Learning Leadership (ITaLL) Model, we focus on providing experiences that align with principals' real jobs while developing principals' understanding of the STEM process and proactively influencing their views of STEM classrooms (Sterrett, Rhodes, Kubasko, Reid-Griffin, Hooker, Robinson, & Ryder, 2018). In the following paragraphs we, informed by their previous research, describe the ITaLL Model for pre-service principals that includes a collaborative activity with prospective teachers around supervision. Within the ITaLL Model pre-service principals (PSP) and pre-service teachers (PST) in secondary level STEM fields share conversations, experiences, and feedback impacting teaching and learning (see Figure 1).

Figure 1:
The Innovating Teaching and Learning Leadership (ITaLL) Model

<table>
<tr><th>Teacher preparation</th><th>Principal preparation</th></tr>
<tr><td>Coursework about teaching</td><td>Coursework about leadership</td></tr>
<tr><td colspan="2">Shared, collaborative field-based experiences, with teaching and leadership components</td></tr>
<tr><td colspan="2">Clinical Internship with more experience with collaborative observations</td></tr>
<tr><td>Completion/ Certification</td><td>Completion/ Certification</td></tr>
<tr><td>Teach in classroom; proactively learn from others</td><td>Lead in school; affirm and share highlights from within</td></tr>
<tr><td colspan="2">Have a discussion together about teaching and learning</td></tr>
<tr><td colspan="2">Reflect on teaching and leading together. . . and change.</td></tr>
</table>

Both PSPs and PSTs complete coursework and field experiences within their university-sponsored programs. When creating the ITaLL Model we identified goals and activities within the courses and field experiences where PSPs and PSTs could benefit and learn from collaborating around supervision (see Figure 2). The goal for PSPs within the ITaLL Model is to provide a context to notice the STEM process and practices during teacher observations with the intent to provide meaningful feedback to PSTs. The goal for PSTs is to receive the feedback and learn how to reflect on their teaching in a nonevaluative way. The effort is designed to create a PSP- and PST-collaborative partnership, to improve the supervision experience and provide a vehicle for meaningful feedback. The participants include PSTs in their final year of a teacher preparation program. They take an instructional methods course related to their content area and complete field experiences in local high schools. The PSPs take a two-

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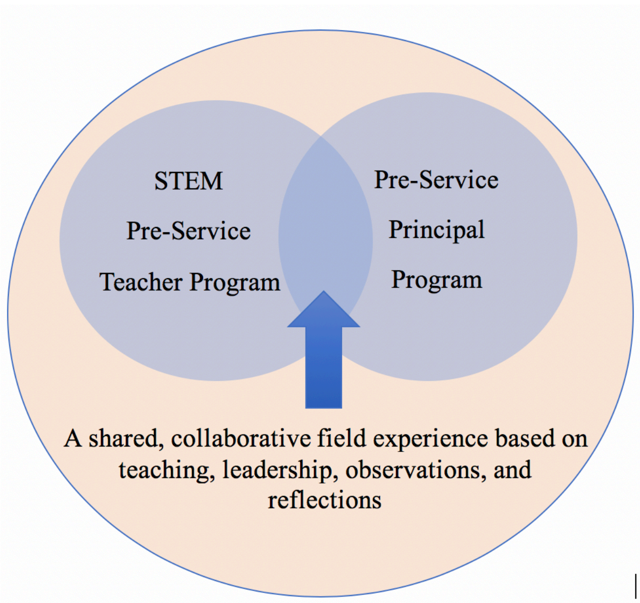
semester internship course, which is facilitated and organized in an online class format.

Figure 2:
The Innovating Teaching and Learning Leadership (ITaLL) Multilayer Applied Learning Project



In the ITaLL Model the PSPs and PSTs progress through three cycles of planning, sharing, and reflecting (Glickman, Gordon, & Ross-Gordon, 2001; Goldhammer, 1969). The planning stage allows the PSPs and PSTs to prepare for an authentic classroom observation. The sharing stage is when the virtual classroom observation takes place. After the observation, the PSPs and PSTs go through the reflection stage to share their thoughts about the observation and to process the learning experience. While the overall structure is consistent over three observation cycles, there are some subtle differences between the first two cycles and the final cycle. In the following paragraphs we provide specific details about the differences.

Observation Exercise – Sample Teaching Video Analysis

Over the first two observation and reflection cycles, the PSTs and PSPs utilize externally sourced teaching videos of authentic STEM-infused classrooms. The Accomplished Teaching, Learning and Schools (ATLAS, National Board for Professional Teaching Standards, 2018) database, a product of the National Board for Professional Teaching Standards certification process, is employed by the ITaLL instructors to serve the PSTs as videos to analyze practice. The PSTs and PSPs watch the short videos that are approximately 15 minutes in length. While the videos stand alone, they do include contextual features such as teacher commentary and instructional materials that serve as supporting documentation for the participants. During these first two cycles the participants, guided by their class instructors, work within their respective groups and courses to complete each cycle.

During the planning stage the PSPs learn about STEM process and practices and classroom walkthroughs. In partnership with their course instructors, the PSPs outline their learning goals for their observations, discuss how to focus their attention on student thinking during the observation, and reflect on how to provide meaningful feedback to teachers. The PSPs review the observation protocols that will be employed during the observation. While PSTs also set learning goals with their course instructors and learn about STEM process and practice, they have a slightly different focus during the planning stage. The analysis they do is to prepare them to notice and interpret student thinking. Given the struggles PSTs have related to noticing student thinking when they observe videos (Jacobs et al., 2010), they initially view the selected ATLAS video prior to coming to class and complete a pre-analysis questionnaire with carefully designed prompts. Upon arrival to class, the participants are organized into small groups to share their recorded observations with their peers. This part of the experience is especially important for PSTs because it gives them a chance to notice and discuss whatever they highlighted as being important when they observed the video.

Next, during the sharing stage, PSTs watch a small segment of the same ATLAS video a second time, together. The purpose is to explicitly highlight a segment of the video where a key instructional moment is taking place. PSPs watch the same video in their respective course and use their observation protocols to collect data and evidence for the goals they designed during their planning stage. During the observation all participants focus their attention on their intended learning goals. They record their observations, document relevant evidence from the videos, and again share their results with their peers. PSPs and PSTs will use similar observation protocols to focus their attention and take notes.

Lastly, during the reflecting stage the participants discuss their observations pertaining to the learning goals. The analysis prompts for the PSPs and PSTs are different. The PSPs use data from their observation protocols and are encouraged to focus on the STEM process. Then the PSPs consider what feedback they might provide the teachers and prioritize the feedback to consider what may be more relevant to share with teachers. The PSTs are encouraged to focus their discussions on student thinking and how the thinking might be connected to classroom instruction. Furthermore, the PSTs are provided a sample of principal feedback and asked to reflect on the idea and consider how they could use the feedback to improve their teaching practice. Throughout this stage all participants are asked to provide evidence or data to support any claims they make about their classroom observations.

Observation Exercise – Teaching Observation

After completing the first two observation and reflection cycles with ATLAS videos, the PSTs and PSPs apply what they have learned and complete a unique third cycle together. The PSTs are asked to record themselves for at least 20 minutes in their field experience in the schools. The videos used during this cycle are from the PSTs' classrooms instead of the externally sourced teaching videos. The recorded video is uploaded to a password protected server and shared with their partnering PSP's. The final teaching observation and reflection cycle provides an authentic experience for both the PSPs and the PSTs.

Again, the planning stage of the cycle allow participants to plan for the observation. For this final cycle the PSTs develop their lesson plans for the high school class they are teaching. They create learning goals for their lessons and consider how their instruction supports students meeting those goals. The PSTs prepare a written context for teaching narrative which will provide more information to PSPs during the next stage. The PSPs will develop, in partnership with the PSTs, the goals for their observations. The PSPs' goals will focus their observation and consequently influence the feedback and reflection. PSPs review their observation protocols to make sure there is alignment between the protocol and their goals.

Next, during the sharing stage, the PSTs teach a class in their field experience and video record their instruction. The PSTs select a 10-minute portion of their video to share with PSPs. The PSTs review and edit their context for teaching narrative and upload their videos and narratives to a password-protected server (i.e., Taskstream). Once the videos and narratives are uploaded, the PSPs observe the videos and read the PSTs' narratives. The PSPs use their walk-through observation protocols to focus their attention on important features of the STEM process in the lesson.

In the last stage of the teaching observation cycle—reflection—PSTs first review and reflect on their videos prior to receiving feedback from the PSPs. The prompts are similar to the sample teaching analysis video prompts, which focus the PSTs attention on student thinking. The PSPs organize their data from the observation protocols and decide what feedback they plan to share with the PSTs. Once the PSPs provide the feedback, there is time set aside for the PSTs and PSPs to have a conversation about the feedback. The conversation about the feedback is essential because it gives the participants time to jointly reflect on the experience and learn about their practice from each other.

Discussion

There is a conflict within the supervision role of principals (Sullivan & Glanz, 2013). On one hand they are tasked with supporting teachers in the instructional process. However, they are also required to evaluate the teacher. We have found that principals clearly want to assist STEM-infused teachers to grow in their professional practice and they offer constructive feedback that applies to general pedagogical skills and strategies that can apply across all disciplines. They maintain high expectations for STEM-infused classrooms and hope to see engaging, hands-on learning that addresses higher order thinking skills. But when asked, the principals quickly identify the multitude of obstacles that they face when actually providing STEM-specific feedback to teachers including a lack of content knowledge in the discipline and a shallow depth of understanding of STEM process and practice. Even among the two principals with backgrounds in STEM content, their understanding of reform-minded STEM process and practices was limited, leading to teacher feedback that wasn't STEM specific. Teacher and principal education programs need to do more to prepare our principals to be successful in the development and support of a STEM-literate teaching force.

Based on research and a need for change, faculty in both the teacher education and principal education programs have come together to design a solution. Working across departments in the college of education, the ITaLL Model has been developed and integrated, bringing together both the pre-service teacher education and the pre-service principal education student populations. Three iterative observation and reflection cycles have been designed to link both sets of students to effective professional practice that benefits STEM supervision. The key components of each cycle include professional planning, peer sharing and active discourse and reflection. This collaborative partnership aims to improve the experience for principal supervisors in training and provide a vehicle for meaningful feedback for pre-service teachers to be used in their emerging practice.

There are limitations and challenges within the engaged work that shouldn't be overlooked. When integrating two distinctly disparate academic programs, there are the challenges of time and resources. The faculty involved on the team represented academic deans, mathematics and science educators, principal educators and assessment specialists. In courses where student collaboration is taking place and are integral to the success of each academic program, the inclusion of another student learning activity presents challenges to faculty and students. Compromises had to be made across programs. Interdisciplinary education in any context is a challenge on many university campuses as programmatic goals, objectives and outcomes must be merged. Certification concerns are always an issue as both programs require state mandates be met. There is unfortunately little time in the course curriculum to define, develop and train principals in STEM content, process, and practice. So, the developers had to be efficient in their expertise and create a learning environment that maximizes the pre-existing skills of the pre-service principal population. As a final note, we believe that we need to demonstrate for our prospective educators how to overcome these challenges to collaborate and create interdisciplinary learning opportunities for students. It is important for university faculty to show ways to collaborate across disciplines as we hope our STEM teachers and principals do the same at the K-12 school level.

Acknowledgments

This article is based upon work supported by the ETEAL Applied Learning Strategic Initiative Award at the University of North Carolina Wilmington. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the university. We are grateful to Justin Fischetti for his contributions to the project through data collection and transcriptions.

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KENAN FELLOWS PROGRAM
FOR TEACHER LEADERSHIP

Journal of Interdisciplinary Teacher Leadership

ISSN 2474-7432

2019, Vol. 4, No. 1

Factors Influencing Student Academic Performance in Online Credit Recovery

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ABSTRACT

Recent estimates show nearly 90% of school districts nationwide offer some form of online credit recovery. Despite its widespread adoption, there is a dearth of research surrounding the suitability of online credit recovery for students. This study examined potential success factors of students enrolled in virtual recovery courses in a school district in the mid-Atlantic region of the United States. Descriptive statistics, chi-square analysis, and binary logistic regression modeling was used for data analysis to account for the influence of student characteristics on credit recovery outcome. Findings revealed that grade-level, IEP status, and middle school End-of-Grade Test results could be linked to achievement in online credit recovery courses. Implications of these findings for educators are discussed

Introduction

While graduation rates across the United States have steadily increased over the past decade, school dropout remains a critical issue. During the 2015-16 school year over 500,000 students dropped out of U.S. schools (McFarland, Cui, Rathbun & Holmes, 2018). The decision to withdraw from school before earning a diploma can have devastating consequences. For instance, high school dropouts have higher rates of unemployment, teen pregnancy, incarceration, homelessness, and mental and physical health problems (Freudenberg & Ruglis, 2007; Stillwell, 2009; Sum, Khatiwada, McLaughlin & Palma, 2009; Varlas, 2005). Additionally, the societal costs for dropping out of high school are staggering. Sum et al. (2009) estimate that a single dropout will cost taxpayers an average of $292,000 over a lifetime due to the costs associated with incarceration, health care, and lack of tax revenue generated.

Bridgeland, Dilulio and Morison (2006) report that credit deficiency is one of the primary reasons students choose to drop out of school. Students who fall behind their peers early in their high school experience face myriad challenges as they attempt to catch up (Watson & Germin, 2008). Traditionally when students have been unsuccessful in a course, they are required to repeat the same course in summer school or the following academic year. With the advent of online learning however, additional avenues have become available for students to quickly obtain credit for courses they were initially unsuccessful in (Carver, Lewis & Coopersmith, 2011). In many cases, credit can be earned during the same academic year that the original course was unsuccessfully attempted. These programs are known as "online credit recovery". Credit recovery is understood as "a structured means for students to earn missed credit in order to graduate from high school" (McCabe & St. Andrie, 2012, p. 1).

Surveys estimate that nearly ninety percent of school districts offer online credit recovery as a means to help students regain course credit and stay on track for graduation (Queen & Lewis, 2011). Despite the widespread adoption of these programs, there is a lack of scholarly research on the effectiveness, rigor, and suitability of online credit recovery (Rickles, Heppen, Allensworth, Sorensen & Walter, 2018). In practical terms, this means students may be enrolled into credit recovery courses by counselors and administrators without completely understanding if this intervention is the most appropriate instructional mechanism for them to regain credit.

This study examines an issue heretofore unexplored, namely is credit recovery suitable for all students? No clear set of characteristics have been identified that influence success in online credit recovery. An investigation of the factors that influence success in online credit recovery would assist school counselors and administrators with the course

ISSN 2474-7432
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enrollment process and save school districts from expending scant resources on a program that may ultimately prove to be unsuccessful for certain students.

Brief Review of the Literature

As an offshoot of online learning, credit recovery grew rapidly as a result of the reforms required by No Child Left Behind (Dessoff, 2009). School districts, under pressure by federal and state mandates to improve test scores and raise graduation rates, found credit recovery to be a cost-effective option to fulfill both needs (Zehr, 2010). Results from a nationwide survey of K12 online learning administered to over 2,500 school district superintendents and administrators showed that credit recovery was one of the most common applications of online coursework (Greaves & Hayes, 2008). Credit recovery has been referred to as "the fastest growing area of online learning" (McCabe & St. Andrie, 2012, p. 1).

Online credit recovery programs typically utilize a mastery or competency-based model (Powell, Roberts & Patrick, 2015). These programs allow students to complete coursework at their own pace by remediating in academic areas where they were found to be deficient (Zenith, 2011). Credit for a previously failed course is awarded after the requisite units have been mastered (McCabe & St. Andrie, 2012).

There is disagreement as to the effectiveness of online credit recovery. An experimental study of Chicago Public Schools students enrolled in Algebra 1 revealed that online credit recovery students had lower passing rates than students who retook the course in the classroom (Heppen et al., 2017). Despite this, there were no significant differences between online and face-to-face students in passing rates in subsequent mathematics courses or their likelihood of being on track for graduation at the end of the second year of high school (Heppen et al, 2017).

Credit recovery programs have been criticized for their lack of rigor and limited oversight (Davis, 2015). Powell et al. (2015) note that many "credit recovery 'solutions' have lowered the bar for passing" (p. 10). This is attributed to pressure school districts are facing to "do something" to raise graduation rates. Additionally, credit recovery has become a multi-billion dollar business. Courseware providers are fiercely competing for multi-million-dollar contracts with states and large school districts. This competition creates powerful commercial incentives to ensure students are receiving credit (Finn, 2012). In many cases this means lower standards and higher passing rates.

Students enrolled in credit recovery courses are generally identified as "at-risk" (Heppen, Sorensen, Allensworth, Walters, Stachel & Michelman, 2014). A review of the literature reveals multiple characteristics and factors that capture the profile of at-risk students. These students typically possess a limited self-concept (Bulger, 2006), doubt their academic capabilities (Bulger, 2006), have limited parental support (Martin, 2006), do not feel supported by their teachers or school (Tompkins & Deloney, 1994), are not encouraged to succeed by their community (Roderick, 1993), and experience an external locus of control (Coleman et al., 1966). These characteristics stand in contrast from the characteristics often associated with success in the online learning environment, including being academically autonomous (Oliver, Kellogg, Townsend & Brady, 2010), socially and emotionally mature (Picciano & Seaman, 2007), in possession of solid time management skills (Lewin et al. 2008), and possessing a developed internal locus of control (Fazey & Fazey, 2001).

Despite this dichotomy, virtual schooling programs "are well positioned to directly address the needs of at-risk learners" (Archambault et al., 2010, p. 3). This investigation examines the factors that influence success for credit recovery students and will better assist educators in leveraging this powerful tool.

Significance of this Study

The U.S. Department of Education reports that approximately 89 percent of school districts in the U.S. offer some form of credit recovery (US DOE, 2018). The International Association for K-12 Online Learning lists credit recovery as one of the chief reasons school districts offer virtual learning (Powel et al., 2015). Despite its widespread adoption, an extensive search of the literature revealed scant research focusing on student factors and characteristics that may influence success in an online credit recovery course.

This research provides school teachers, counselors, advisors and administrators insight into credit recovery course success factors. This knowledge

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will provide school personnel the tools necessary to place the at-risk students most likely to succeed into credit recovery sections. At a time when district budgets nationwide are still reeling from the effects of the Great Recession, this could save school systems valuable resources. Furthermore, with a solid understanding of the type of student that is not likely to be successful in the online environment, districts could save at-risk students valuable time. Lastly, as the pressure to raise graduation rates remains a constant weight on shoulders of school districts, a more comprehensive understanding of the type of at-risk student likely to be successful in online credit recovery can help schools refine and implement dropout interventions.

Purpose and Research Questions

In an effort to add to the existing literature on credit recovery, this study examines an issue heretofore unexplored, namely is credit recovery suitable for all students?

To date, no clear set of characteristics have been identified to predict success in online credit recovery. Liu and Cavanaugh (2011 & 2012) developed a model which investigated success factors of students in high enrollment K12 virtual school courses, examining student characteristics including gender, race, grade-level, and exceptionally. Building on the work conducted by Liu and Cavanaugh, this research examines the success factors of students enrolled in online credit recovery for core academic subjects, including English, mathematics, science and social studies. These disciplines were selected, as successful passage is necessary in order to graduate from high school in the state where the study took place.

The variables of interest in this study include: gender, race, grade-level, discipline/behavior history, exceptionality/IEP status, Academically/Intellectually Gifted (AIG) status, middle school mathematics End-of-Grade (EOG) assessment results, middle school reading EOG assessment results, and middle school science EOG assessment results. These constitute the study's independent, or predictor, variables. Student outcome in the credit recovery course constitutes the dependent variable for the study. Per the policy in the state where the study took place, students do not receive a letter grade when they complete their credit recovery coursework; rather those who successfully complete all requirements receive a grade of P (pass). Unsuccessful course outcomes are listed with a F (fail) or I (incomplete).

The research questions in this study included:

1. Does a student's gender and/or race predict achievement in online credit recovery core discipline courses? If so, how?
2. Does a student's grade-level predict achievement in online credit recovery core discipline courses? If so, how?
3. Does a student's discipline history predict achievement in online credit recovery core discipline courses? If so, how?
4. Are there differences between credit recovery students with Individualized Education Plans (IEPs) and those without IEPs, with respect to their academic achievement in online credit recovery core discipline courses?
5. Are there differences between Academically/Intellectually Gifted (AIG) credit recovery students and non-AIG students, with respect to their academic achievement in online credit recovery core discipline courses?
6. Do middle school state-standardized reading, mathematics, or science assessment results at any grade-level predict student achievement in online credit recovery core discipline courses? If so, how?

Methodology

Participants and Data Collection

The target population for this study is high school students who enrolled in an online credit recovery course in a school district in the mid-Atlantic region of the United States. The school district examined utilizes two credit recovery courseware providers: NovaNET and Apex Learning. NovaNET identifies students' current level of performance by analyzing the results of a pre-test. The courseware provides an individualized remediation experience through the use of adaptive instructional models based on the results of the pre-test. After completing the requisite lessons and activities, students take a post-test; if students score an 80 or above on the post-test unit exam, they are deemed to have achieved mastery

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of the subject (Pearson, 2004). Apex Learning leverages video, graphics, animation, and audio to support at-risk students who may not read, or otherwise perform, at grade-level. Apex Learning's credit recovery courseware has been lauded as more rigorous than other credit recovery providers (Sapers, 2014). The school district contracted with Apex Learning specifically because of their reputation for rigor. All instruction was conducted in a computer lab with no in-person meetings with teachers. In the computer lab students had access to a teachers' aide who could assist with technological matters and basic instructional issues.

Table 1: *Academic core disciplines and associated courses*

Discipline	Core Courses
English	English I English II English III English IV
Mathematics	Integrated Math I / Algebra I Integrated Math II / Geometry Integrated Math III / Algebra II Higher Level Mathematics course
Science	Earth and Environmental Science Biology Chemistry or Physical Science
Social Studies	World History US History Civics & Economics

The primary source of data for this study is final grades from credit recovery courses for high school students enrolled in academic core discipline courses during the 2014-2015 and 2015-2016 school years. Table 1 shows a list of the academic core discipline courses. These courses were selected as they are required for graduation. Data were collected via reports generated from the student data information management system utilized by public schools within the state. When final grades are queried, individual student data can be linked via relational database to academic, demographic, and historical information on each student who received a grade in a credit recovery course.

Table 2 provides student demographic information and descriptive statistics for the independent variables. The sample consisted mostly of boys (n = 205, 59.1%). Most of these students were classified as Black (n = 121, 34.9%), while 114 students (32.9%) classified themselves as Hispanic, 100 classified themselves as White (28.8%), and 12 classified themselves as Other (3.5%). Most students were in the 11th grade (n = 129, 37.2%), did not have an IEP (n = 305, 87.9%), and were not identified as AIG (n = 329, 94.8%). Most students had no disciplinary incidents reported (n = 210, 60.5%). Of those who had disciplinary incidents on record, the mean number of incidents was M = 6.76 (SD = 8.34). Most students scored a level III in Math in 6th (n = 159, 46.9%) and 7th (n = 128, 37.8%) grades, while the majority of students scored a level 1 in 8th grade (n = 140, 41.7%). The majority of students scored a level I in Reading in each grade (6th: n = 115, 34.3%; 7th: n = 116, 34.4%; and 8th: n = 135, 39.9%). In 8th grade Science, most students scored a level 1 as well (n = 128, 38.8%). The majority of students took Social Studies credit recovery course (n = 171, 49.3%).

Table 2: *Frequencies and percentages for categorical variables*

Variable	N	%
Gender		
Female	142	40.9
Male	205	59.1
Race		
Black	121	34.9
Hispanic	114	32.9
White	100	28.8
Other	12	3.5
Grade Level		
9^{th}	84	24.2
10^{th}	92	26.5
11^{th}	129	37.2
12^{th}	42	12.1

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Variable	N	%
IEP Status		
Has IEP	42	12.1
Does not have IEP	305	87.9
AIG Status		
Yes	18	5.2
No	329	94.8
Incidents		
No Incidents	210	60.5
One or more incidents	137	39.5
Math 6th Grade		
I	54	15.9
II	103	30.4
III	159	46.9
IV	23	6.8
Reading 6th Grade		
I	115	34.3
II	68	20.3
III	136	40.6
IV	16	4.8
Math 7th Grade		
I	94	27.7
II	89	26.3
III	128	37.8
IV	28	8.3
Reading 7th Grade		
I	116	34.4
II	96	28.5
III	91	27.3
IV	33	9.8
Math 8th Grade		
I	140	41.7
II	95	28.3
III	82	24.4
IV	19	5.7
Science 8th Grade		
I	128	38.8
II	78	23.6
III	80	24.2
IV	44	13.3
Discipline		
English	37	10.7
Math	80	23.1
Science	59	17.0
Social Studies	171	49.3

Coding

During the data analysis, all categorical variables were coded accordingly. Table 3 shows the coding information.

Table 3: *Coding of independent variables*

Gender	0: male 1: female
Race/Ethnicity	0: White 1: African American/Black 2: Hispanic/Latino 3: other
Grade Level	9: 9th grade 10: 10th grade 11: 11th grade 12: 12th grade
Academically / Intellectually Gifted (AIG)	0: not identified as AIG 1: identified as AIG
Individualized Educational Plan (IEP)	0: no IEP on file 1: IEP on file
Discipline/incident history	0: no incidents on file 1: incidents on file
Middle school mathematics End of Grade (EOG) standardized assessment	1: Level I 2: Level II 3: Level III 4: Level IV
Middle school reading EOG standardized assessment	1: Level I 2: Level II 3: Level III 4: Level IV
Middle school science EOG standardized assessment	1: Level I 2: Level II 3: Level III 4: Level IV

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The dependent variable, success or failure in a credit recovery course, is included in each student's record. For the purposes of this study, a value of zero (0) represents a student who failed or received an incomplete in the recovery course. A value of one (1) represents a student who passed the recovery course.

Research Design

This study is descriptive in nature and as such, non-experimental. The study aims to identify certain factors that influence success in online credit recovery courses without intervening within the courses themselves. Demographic and academic background information was collected from participants in all academic core high school credit recovery courses from the 2014-15 and 2015-16 school years. The initial analysis combines recovery data from all core courses. Ancillary analysis parses credit recovery data by subject. To ensure there is sufficient power for this data analysis, credit recovery course data is combined into the four overall core disciplines: English, mathematics, science, and social studies. For example, results from Earth & Environmental Science, Biology, Chemistry, and Physical Science are grouped together into a discipline titled "Science."

Data Analysis

Univariate analyses were conducted to explore the relationship among the variables gender, race/ethnicity, grade level, AIG status, IEP status, and discipline/incident history, and the dependent variable. Group comparisons for categorical variables were performed using Binary Logistic Regression and Chi-Square analysis. The Chi-Square analysis was utilized to determine if there was a significant relationship between two categorical variables. Binary logistic regressions were utilized to identify the effect that one or more predictors have on a single dichotomous dependent variable. A p value of 0.05 is generally used as the level of significance when examining the results of a Chi-Square analysis and Binary Logistic Regression. Odds ratios were then calculated to examine the practical significance of the findings.

Results

The results of the analyses indicate that gender and race do not demonstrate a significant effect on credit recovery course outcome (χ^2 (4) = 8.42, p = .077). Grade level is found to have a strong and significant effect on course outcome (χ^2 (1) = 19.88, p < .001), (B = 0.92, p < .001). The Exp(B) value indicates that for every 1 unit increase in grade level, students have a 2.52 increase in the likelihood of passing their course. The full results of this analyses are presented in Table 4.

Table 4: *Results of the Binary Logistic Regression using Grade Level on Outcome*

Variable	B	SE	Wald	P	Exp(B)
Grade Level	0.92	0.23	16.52	< .001	2.52

Note: (χ^2 (1) = 19.88, p < .001)

No significant effects are demonstrated when examining disciplinary incidents (χ^2 (1) = 2.11, p = .146). There are differences in student outcome based on whether or not an IEP was implemented (χ^2 (1) = 8.51, p = .004). Of those students who had no IEP, slightly more students passed than expected (n = 282 [276.90]). Within this no IEP group, 92.5% of students passed. Of those students who had an IEP, slightly fewer students passed than expected (n = 33 [38.10]). In this IEP group, 78.6% of students passed. Full results are presented in Table 5.

Table 5 *Results of the Chi-Square Comparing IEP Status and Student Outcome*

	Student Outcome	
IEP	Fail	Pass
Yes	23 [28.10] 7.5%	282 [276.90] 92.5%
No	9 [3.90] 21.4%	33 [38.10] 78.6%

Note: (χ^2 (1) = 8.51, p = .004). Expected counts are in brackets. Percentages are within IEP groups.

There is no significant difference in student outcome based on AIG status (χ^2 (1) = 1.93, p = .165). The results of the overall binary logistic regression were significant when examining 6-8th grade math, reading, and science End-of-Grade Test scores (χ^2 (7) = 18.24, p = .011). While the overall model was significant, no variable was individually significant, suggesting that they only effect student outcome when combined in the model. Table 6 details the results of the analyses on individual End of Grade exams.

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Table 6: *Results of the Binary Logistic Regression using Math, Reading, and Science End of Grade Scores on Outcome*

Variable	B	SE	Wald	P	Exp(B)
Math 6th Grade	0.22	0.37	0.37	.541	1.25
Reading 6th Grade	-0.40	0.37	1.20	.274	0.67
Math 7th Grade	0.52	0.35	2.31	.129	1.69
Reading 7th Grade	-0.20	0.38	0.28	.597	0.82
Math 8th Grade	0.27	0.39	0.46	.496	1.30
Reading 8th Grade	0.26	0.39	0.43	.512	1.30
Science 8th Grade	0.52	0.33	2.41	.120	1.67

Note: χ^2 *(7) = 18.24, p = .011*

Discussion and Implications

In this study the influence of several factors on the outcome of students enrolled in online credit recovery courses was investigated. These factors include gender, race, grade level, discipline history, IEP status, AIG status, and middle school reading, mathematics, and science End of Grade (EOG) results. Each of the variables included in the estimating equation are examined in light of their relationship with student academic achievement in other studies.

Influence of Grade Level in Online Credit Recovery

Dowling (1994) reported that at-risk high school students could be classified into two groups: freshmen and sophomores, and junior and seniors. Dowling discovered that an at-risk population of freshmen and sophomores was significantly more likely to not complete a high school dropout prevention program than an at-risk population of juniors and seniors. The difference in the success of the dropout prevention program with the younger and older students led Downing to suggest that the root cause of the younger student's lack of success may be due to factors other than instructional strategies The author concluded that grouping all high school students together and providing the same instructional strategies was not an effective strategy for dropout prevention.

Examining the results of this research question through the lens of Finn's (1989; 1993) participation-identification model of school engagement provides additional perspective. The theory suggests that positive student engagement at school directly relates to students' chances for successful school completion. As older students have experienced more success in their secondary coursework, they may be more likely to complete their online credit recovery coursework. Conversely, younger students may have not had the opportunity to experience much, or any, success in their secondary coursework, so their experience is marked by limited school engagement. With such limited school engagement, younger students may not see the value in completing their credit recovery coursework, whereas older students who have seen success do.

In their report tracking students who return to school after dropping out, Kolstad and Owings (1986) found that the percentage of those who ultimately complete high school was significantly higher for those who were classified as upperclassmen than those classified as underclassmen. 41% of students classified as seniors when they dropped out successfully earned a high school diploma when they reenrolled. This is compared to 37% of juniors and 27% of sophomores. Kolstand and Owings did not have data on freshmen who returned to school after dropping out but they surmise that the completion rate would be lower than 27%. These findings, coupled with Dowling's (1994) and Finn's (1989; 1993) can be taken as an indicator that underclassmen need additional supports that upperclassmen do not. The implications as related to online credit recovery are clear: additional academic support and counseling for underclassmen are crucial to ensure success. As these at-risk students progress through their high school experience they will become more self-sufficient and the need for the additional supports will decrease, however freshmen and sophomores should not be expected to complete their recovery coursework without assistance from school personnel.

Influence of IEP Status in Online Credit Recovery

These findings have interesting implications to credit recovery researchers. In their 2011 annual report, the North Carolina Virtual Public School reported that students with disabilities are severely underrepresented in research studies (NCVPS, 2011). These findings have been echoed by several researchers in the years since (Burdette, Franklin, East & Mellard, 2015; Smith &

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Buurdette, 2014). Despite the lack of research, virtual education for exceptional students has been gaining momentum nationwide (Cavanaugh, Repetto & Wayer, 2011). A report published by the National Association of State Directors of Special Education noted that many state run virtual schools provide services to students with disabilities, but there were large inconsistencies in the implementation and services offered to this population from state-to-state (Müller, 2009).

Virtual schooling provides many of the same benefits to students with disabilities as it does to at-risk students in general education. These benefits include individuated instruction, self-paced courses, the availability of interactive course materials and supplemental resources, frequent and immediate feedback, and the ease of communication with peers (Fichten et al., 2009; Rhim & Kowal, 2008). Despite these benefits, there are several challenges that virtual schools face when addressing the needs and concerns of online students with disabilities. These include the inaccessibility of websites and learning/course management systems, the limited accessibility of audio and video materials, inflexible time limits built into online exam software, the conversion of PowerPoint, PDF, and other file formats into a format compatible with screen-reading software, and the cost associated with revising curriculum for accessibility and providing certified personnel (Fichten et al., 2009; Müller, 2009).

Despite the myriad challenges associated with providing virtual education opportunities for students with disabilities, it is expected that virtual schools will continue to see an increase in this population's enrollment as educators recognize online schooling as a viable educational opportunity for at-risk students. However, educators must be cautious when determining what students to enroll in online credit recovery courses. By its very definition, having an IEP means a student has an "individualized educational plan." As noted in the literature though, it has proven difficult for some learning management systems to customize or "individualize" coursework for students with disabilities who require specific accommodations. While technology will undoubtedly continue to improve in the years ahead, the onus is on school counselors, administrators, and special education personnel to ensure that any credit recovery courseware utilized meets the specific needs of students with an IEP prior to their enrollment in a course. Online credit recovery is a viable option for students with disabilities, but additional efforts must be made to ensure that online credit recovery is as accessible to students with disabilities as it is to students in the general education environment.

Influence of Middle School Mathematics, Reading, and Science End-of-Grade Test Results in Online Credit Recovery

In their examination of Philadelphia public school students, Neild and Balfanz (2006) discovered that state administered standardized test scores could be used to predict students who would eventually drop out of high school. Specifically, students who scored extremely low on their 8th grade reading assessment exam had at least a 50 percent chance of dropping out. The researchers also discovered that of the Philadelphia students who dropped out in 9th or 10th grade, a majority had a 5th grade equivalent or below on their 8th grade reading and mathematics assessment results (Neild & Balfanz, 2006). These findings support the belief that a lack of the fundamental reading and mathematics knowledge typically gained in elementary school can have major implications later in a student's academic career, possibly even causing them to dropout.

The state-standardized assessment results utilized in this study can assist educators in understanding individual students' fundamental reading, mathematics, and science skills. While no specific middle school assessment exam was statistically significant in predicting outcome in online credit recovery, there is still value in using assessment results to predict preparedness for recovery coursework. Individual teachers, counselors, and administrators do not have the time or statistical expertise to combine the state-standardized assessment results of every at-risk student into a model prior to enrolling them in recovery courses; fortunately, this is not necessary. Already, many states utilize statistical modeling of common assessment results for predictive probabilities and value-added educational benchmarks (SAS, 2016). The school district where this research data originated subscribes to SAS EVAAS for K12. This software builds on the Tennessee Value-Added Assessment System

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methodology developed by William Sanders and his research team at the University of Tennessee, Knoxville to enable educators to recognize progress and growth over time and predict success probabilities in the future (SAS, 2016). While not all states and school districts subscribe to value-added educational statistical packages, the technology is available and accessible. By utilizing educational statistical software services built around multivariate, longitudinal modeling, educators can make informed choices about enrollment of specific students into online recovery courses (Wright, Sanders & Rivers, 2006).

Conclusion and Future Study

Grade Level Impact

Given the dearth of research on success factors in online credit recovery, the present study investigated the influence of several factors on student outcome in core courses to explore success in the virtual recovery environment. The effect of grade level on recovery outcome warrants attention. While many underclassmen have the capacity to be successful in online recovery, factors such as maturity and previous academic success must be considered prior to enrollment. Any virtual learning experience requires a degree of self-discipline; it does a disservice to underclassmen to enroll those who do not have the self-reliance and discipline necessary to be successful. Upperclassmen who are closer to graduation may see online credit recovery as a means-to-an-end. These students are better equipped to envision life after high school and as such are in a better position to see the value of online recovery. Given the lack of recent literature on high school completion by upperclassmen vs. underclassmen, additional study is reasonable. Research centered around motivation, maturity, and prior academic success in their academic career, should all be considered.

IEP Status Impact

The effect of IEP status on credit recovery outcome cannot be overlooked. Students with documented disabilities often require additional learning supports and interventions that are not inherent or built into online credit recovery platforms. Further, students with documented disabilities may face accessibility issues with the software itself. Before enrolling any student with an IEP in an online recovery course, school personnel must ensure not only that the software meets the specific physical needs of the student, but that the student has the requisite off-line supports necessary for them to be successful, much as they would have in a traditional brick and mortar classroom. While broad in scope, it should not be assumed that recovery programs will provide complete end-to-end support on their own. Future research should examine the benefits and potential challenges that students with documented disabilities could face if enrolled in recovery courses. This examination should also provide enrollment managers, including teachers, counselors, and administrators, specific guidelines on how to best support students with IEPs as they complete their virtual recovery coursework.

End-of-Grade Test Score Impact

Standardized test scores have the potential to be one of the most powerful yet problematic tools for practitioners. Currently, statistical software packages like SAS's EVAAS for K-12 are used to predict the raw score a student will obtain on future state administered standardized assessments (SAS, 2016). These predictions are based upon a student's performance on previously administered assessments. While not without significant limitations (Amrein-Beardsley, 2009), educators from states and districts that utilize value-added statistical packages based upon state-standardized assessment test results would be remiss if they did not take advantage of the predictive capabilities of the software. It must be noted that no one standardized assessment can predict student outcome in online credit recovery, however with the statistical modeling provided to educators via packages like SAS's EVAAS for K-12, a student's entire history of assessment results can be combined to predict performance in future classes. Unfortunately, at this time, statistical modeling techniques like this may not be an available option for course enrollment personnel such as counselors and school administrators. And even if it were, no educator should base their enrollment decisions on the results of a statistical model alone; a tool like this could provide an argument for enrollment in an online credit recovery course or a justification for an alternative option. Future researchers should examine the predictive capacity of EVAAS and EVAAS-like

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systems to optional scholastic opportunities like virtual credit recovery to determine if there is a way to reliably predict outcomes.

Final Thought

Virtual recovery has been in existence for over 15 years, but much is still unknown about the appropriateness of this educational intervention for at-risk students. This study is but the first sentence in what hopefully will be a deep and robust conversation about the factors that influence success in online credit recovery.

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KENAN FELLOWS PROGRAM
FOR TEACHER LEADERSHIP

Journal of Interdisciplinary Teacher Leadership

ISSN 2474-7432

2019, Vol. 4, No. 1

A New Paradigm for STEM Learning and Identity in English Language Learners: Science Translation as Interdisciplinary, Multi-Modal Inquiry

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ABSTRACT

This two-year case study examined multi-modal, interdisciplinary approaches to engage both immigrant English Second Language (ESL) and English Language Learners (ELL) in STEM (science, technology, engineering, math) learning and to build STEM identity and self-efficacy. Leveraging innate abilities, multiple intelligences, and self-identified interests, children in Grades 3 through 8, new to America and STEM, became inquiry-based researchers of sound-making, soundscapes, and nonverbal communication systems in diverse species including human music-making using technology, analysis, communication research, and observation skills. Using generative and lateral thinking methodology for science translation, interdisciplinary methods, and team-based learning, the students demonstrated increased STEM interest, STEM learning, and STEM skill sets while developing self-efficacy as STEM learners and communicators.

Key Words: *science education, immigrant, English Language Learners (ELL), multi-modal learning, interdisciplinary, learner-centered, knowledge translation.*

Background

It is widely observed that despite many efforts by researchers, new policies and programs, educational equity for underrepresented ethnic minority students (URMs) in the United States is an elusive and mostly failed effort (Chemers et al, 2011, p. 442). It is further acknowledged that "Science education has largely been unsuccessful in reaching ELL (English Language Learner), Latino, Native American, African American and other non-mainstream student groups, who remain underrepresented in the field of science" (Meyer & Crawford, 2011). Immigrant children represent nine percent of all U.S. public school students, 4.6 million of which are ELLs whose numbers are growing (DOE, 2015). These students face substantive barriers to full participation in science, technology, engineering, math (STEM) education, often living in intensely segregated, low-income communities with under-resourced schools, and centered in families where parents may have little formal education or familiarity with US educational systems and career pathways (Crosnoe & Turley, 2011).

A growing body of research in the social sciences, psychology, and education suggests ways to counter these forces and to build inclusive pipelines for STEM participation in diverse populations. Common to these findings is the importance of 1) supporting these children's identity and belonging, which is developed through being recognized by oneself and others as capable, valuable, and competent in a given field (Carlone, Scott, & Lowder, 2014; Luehmann, 2007; Buxton & Provenzo, 2010), and 2) reevaluating learning environments and methods (Robinson & Aronica, 2015; Meyer & Crawford, 2011) in support of creating an authentic immigrant context for STEM knowledge construction and communication. Developing a productive STEM learner identity involves providing opportunities to develop and deepen STEM content understanding and practices, to contribute to a community of learners, and to develop a sense of self-efficacy as a STEM learner (Calabrese Barton & Tan, 2010; Herrenkohl & Mertl, 2010). Research in the learning sciences also stresses the importance of engaging student interest and participation through leveraging personal interests and histories (National Research Council, 2015). To broaden participation in STEM learning, it is essential that programs position students' interests, histories, and skills as assets, or "funds of knowledge" (Moje et al., 2004; Moll, Amanti, Neff, & Gonzalez, 2009) – building blocks central to the purpose and activity of the program (Eisenhart, Finkel, & Marion, 1996; Lemke, 2001).

There is much scholarship documenting culturally diverse and ELL youths' disenfranchisement from STEM disciplines (Bang & Medin, 2010; Calabrese Barton, Tan, & Rivet, 2008; Rahm, 2014; Thompson, 2014). Indeed, much of this research describes formal

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STEM education as "racialized" and "gendered," and contends that formal STEM education tends to marginalize the funds of knowledge and experiences that culturally diverse and ELL youth bring to STEM learning environments. Further, such environments may provide few "identity resources" (Nasir, 2012) for youth to enable them to take up new roles or responsibilities that position them as competent or developing experts (Bell et al., 2013). Hence, there is a great need to understand how STEM learning environments can broaden these marginalized youths' participation in STEM in ways that afford, rather than constrain, the range of available identity resources.

The current challenge to equip students with 21st century skills includes the exploration of intersections among core subjects to prepare children for "the competitive, complex, and connected world they will inherit" (Partnership for 21st Century Skills, 2007, p. 2). An interdisciplinary approach provides students ways to develop more knowledge and skills and possess better mastery of the materials than discipline focused traditional programs (Bransford, 2000). Using funds of knowledge with inquiry-based learning, students can explore a trilateral collaboration in concepts, explanations, and learning outcomes that expand from collecting data and relevant information to include comparative learning, increase awareness of science as important to everyday life, and extend knowledge through translations of science into other spheres of knowing, intelligence, and communication.

We argue that if we are to expect students to apply "novel ideas to new situations," we must provide opportunities for students to practice science in many contexts (AAAS, 2009). Thus, this case study investigates how individual and collective STEM development can unfold in a cultural milieu that uses science as a framework to engage multiple intelligences in support of a collective, interdisciplinary learning culture. The study tracks how a STEM design grounded in multi-modal learning and science translation afford a STEM approach that is inventive, innovative, and meaningful for underrepresented ethnic minority children. By employing multi-modal, interdisciplinary methods with science translation, immigrant/ELL youth strengthened STEM interest and skills and increased STEM identity and STEM self-efficacy.

The Study's Goals and Objectives

During 2014-16, the Burroughs Wellcome Fund supported UBEATS (Universal BioMusic Education Achievement Tier in Science), an informal STEM program developed as an out-of-school intervention for immigrant children in Guilford County. (https://research.uncg.edu/spotlight/wild-music-festival-brings-immigrant-children-to-stem/). The project, a collaboration of the University of North Carolina at Greensboro's (UNCG) BioMusic Program and its Center for New North Carolinians (CNNC), the Greensboro Science Center (GSC), and the Guilford County School System, targeted children of immigrant families in the county, which has one of the fastest growing communities of new immigrants in the Southern United States; the majority coming from Central America and Southeast Asia, as well as Africa and the Middle East. (See Supplementary Materials).

Using an array of activities, the UBEATS student participants (Year 1: 50; Year 2: 81) in grades 3-8 studied music-making and animal communication systems as scientists. The program, led by UNCG Director of the BioMusic Program, professional teachers in STEM education and ELL, technology specialists, science center staff, a children's theatre professional (Year 2) and four immigrant high school student interns, created learning activities based on a BioMusic curriculum grounded in the National Education Standards (National Research Council, 1996). UBEATS programming was structured to include two annual one-week summer camps, each followed by a once-a-month three-hour club meeting over two academic years (AY) at the Greensboro Science Center (GSC). Student learning activities featured sonic communication in humans and other species, data collection of terrestrial and marine species, hands-on experiences with audio technology and analysis programs, and student research of families' signifying sounds from countries of origin.

UBEATS curriculum, content, and activities center on sonic communication systems and human music-making, an untapped or rarely employed resource for funds of knowledge. Based on BioMusic research (Gray, 2014), animal behavioral and communication systems, and multi-modal information processing, UBEATS science learning proceeded by examining sonic communication systems and music-making using comparative analysis, technology manipulation, and science translation. Because UBEATS defines sonic communication and music-making as a biotechnology, content and methods are designed to stimulate learners to explore sound-making as survival strategy, analogous music-like structures, and sound/time perception in themselves and other species, while exploring the evolutionary trail of communication systems in an array of acoustic environments. This approach enables children to use their innate musicality as a basic tool in discovering how animal communication relates to human music making, while enabling students to affirm habits of discovery and inquiry (Carrier, 2012). Thus, UBEATS STEM content reflects interdisciplinary, firsthand, multi-modal approaches to knowledge-building that are found to be hallmarks of powerful learning in formal and informal environments and key attributes of learning for preparation for the 21st century workforce (National Research Council, 2009, 2012, 2015).

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This Study investigated whether and how non-traditional STEM learning methods based in the exploration and production of communicative behaviors can promote and broaden STEM identity and STEM self-efficacy in English speaking immigrant and ELL children. Our work examined two broad questions:

1) Will using interdisciplinary cross-cutting BioMusic concepts and practices that exercise innate human musical capacities underlying environmental information processing, communication, and culture creation increase and improve the multiple domains deemed critical to STEM competence, identity, and self-efficacy?

2) Can science translation using practices grounded in both the arts and sciences enhance STEM identity and self-efficacy in immigrant/ELL youths?

Cross-Cutting Content and Activities

What is BioMusic? BioMusic is a multi-disciplinary field - biology, animal communication, ethnomusicology, music theory, neuroscience, physics, bioacoustics, and evolutionary biology - that studies music's biological and cognitive elements to explore relationships and meaning-making in humans and non-humans (Gray et al, 2001). BioMusic research focuses on meaning-making using auditory perception, including the semiosis of sound in the social environment, as well as commonalities of musical sounds in all species, in relations of sonic patterns, frequencies, rhythms, volume, structures, significance, and their role in biodiversity (Gray, 2015).

The UBEATS program content and activities, based on and elaborated from BioMusic curriculum developed with a National Science Foundation STEM education grant ("UBEATS," 2013) to the University of North Carolina-Greensboro (UNCG) and North Carolina State University's Kenan Fellows Program, engaged the students to:

- Explore aural non-verbal structured communicative behaviors in humans and other species;
- Participate in real-time activities/games that reveal how time, frequency, amplitude, and memory impact animal/human communication systems;
- Explore environmental acoustics in animal behavior, adaptation, and sustainability;
- Explore the musical brain as a neurological communication system;
- Explore relationships between animal communication behavior and physical properties of sound in diverse environments (soundscapes);
- Record local soundscapes and use sound analysis software;
- Utilize sound technology for data collection and for creative purposes;
- Explore innovative ways to use symbols to represent sound;
- Explore live animal husbandry and habitat requirements for real-time engagement;
- Provide STEM career events;
- Create Participation for families in STEM events;
- Present parent showcases;
- Design & produce translations of artifacts that blend aspects of creative expression and youths' interactions with the natural world.

Specifically, this study looked to design ways to affect the significant impacts of cultural, economic, and developmental differences of immigrant/ ELLs while broadening and strengthening their goals, expectations, and future thinking. To address these, UBEATS developed learning activities in the second year that supported the translation of science knowledge as a strategy for immigrant/ELL learners to personalize STEM relevancy, convey their knowledge, and build self-efficacy.

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UBEATS Methods, Figure 1

Build Competence in STEM skills	• Explore aural non-verbal structured communicative behaviors in humans and other species. • Demonstrate that using symbols to capture auditory events enables students to develop STEM analytical skills and develop technology skills. • Explore physics of sound and sound's physical/neurological processing pathways for multiple species. • Explore the effects of environmental sonic changes, adaptations and behaviors that enable animals (including humans) to survive in changing habitats. • Explore how animals meet their needs by using sonic behaviors in response to information received from the environment. • Experience and practice audio research techniques and methods in controlled and wild environments.
Build Competence in using technology	• Offer opportunities to record sonic data in controlled and wild environments using diverse recording technologies (terrestrial and marine). • Experience sound analysis techniques that use symbols to capture complex auditory events.
Build STEM Identity	• Offer multi-modal opportunities to develop STEM enthusiasm, conceptual and technical knowledge, and STEM identity. • Offer students opportunities to engage in public presentations, to share their research and knowledge with their families, to build interest in STEM.
Build STEM self-efficacy	• Build on motivating and engaging children through their innate interests in music, animals, and team-based problem solving. • Engage in the process of science translation.
Broaden Awareness of STEM across disciplines	• Focus on the physical properties of sound and how auditory systems are used for observation and sense-making. • Provide access to live animals at the GSC to increase STEM knowledge about the role of sound in animal behaviors, sustainability, management, and biodiversity.
Encourage Positive Attitudes toward STEM oriented behaviors and relevance	• Provide research activities online, at home, and at UBEATS project sites that link systems thinking about sounds to children's everyday lives including humans, other animals, and sound environments.
Increase Knowledge of STEM degree paths	• Utilize opportunities in UBEATS lessons to provide students with pathways for sound-related degrees and future career information. (bioacoustics, acoustics, audiology, etc)
Stimulate Interest in STEM Careers	• Provide access to in-person early career STEM role models in diverse career paths. • Provide experiences with new, non-verbal time/sound therapies and medical research.

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Year One Methods

YEAR ONE: UBEATS initial focus centered on the physical properties of sound and how the auditory system is used for observation and sense-making in humans and other species. Children used iPods, field recorders, a shotgun microphone, and a hydrophone to experience diverse sound environments and learn about ways that sound technology and sound analysis techniques provide research opportunities. Year One's activities at UBEATS camp, at a field trip to a state park, and at AY club meetings at the science center offered multiple opportunities to explore wild environments and animals using symbols to capture auditory events and enabled students to develop analytical and technology skills to link systems thinking about sounds of humans, other animals, and sound environments to their everyday lives. To increase STEM knowledge about the role of sound in biodiversity, the GSC provided access to their wide range of resources, including habitats of resident terrestrial and marine animals, enabling students to collect data, sound recordings, and observational details during changing seasons and environments.

Information about career paths and opportunities was provided by invited early career scientists in bioinformatics, wildlife preservation, and neuroscience, as well as animal caretakers at the GSC who gave in-person presentations at club meetings about the scope of their careers, educational arcs, and how sound is used in their field. Each speaker included detailed information about their personal progression from high school to higher education, and how and why they followed their career paths.

Building Family Involvement. UBEATS students and families received free annual passes to the GSC during Year One and Two to encourage family visits and to support students' interests beyond UBEATS planned learning activities. To enable greater family participation at annual capstone events (The Wild Music Festivals), immigrant community leaders greeted families, and free transportation and welcoming signage in 5 languages was provided. During each year's Wild Music Festival, participating children presented a special program in the GSC's OmniTheater for their families supported by multiple translators, provided an overview of their UBEATS activities, and concluded with a reception for the children and their families.

Student Documentaries. Four high school immigrant students (countries of origin: Liberia, Burma, Mexico, and Vietnam) served as mentors during Years One and Two, supporting learning activities and working with the UBEATS Learning Leaders. Working as a collaborative team and mentored by media professionals, they also designed and produced two annual Student Documentaries that reflected their perspectives on the meaning and importance of UBEATS. They learned video production and editing techniques, interviewed key personnel, and shot additional video at community sites for each year's five-minute UBEATS documentary (UBEATS H.S. Student Mentors Documentary," 2015).

YEAR One - Capstone Event. The Wild Music Festival's (WMF) inclusion in the GSC's public offerings, provided ways for typical science museum visitors and families to learn about the children's UBEATS activities. Year One's WMF featured exhibits of students' recordings of GSC resident species with a site map of the recordings and an exhibit of audio samples based on the children's research of their family elders' memories of signifying sounds from their countries of origin. This also included a world map of specific countries represented. Participating students were tasked with explaining their STEM experiences and new knowledge to their families and the public.

YEAR ONE Results and Discussion: The first year's data, using surveys and focus groups following the opening camp experience, indicated the following:

- 91% of participants indicated increased interest in doing science;
- 85% indicated increased understanding of science's importance in their lives;
- 65% indicated science is a favorite subject;
- 82% indicated that they had good feelings about science;
- 78% indicated an increased recognition of science's importance in understanding the world;
- 82% reported increased interest in pursuing future science careers.

These results provided data that the project's educational approach using innovative multi-modal BioMusic curriculum as the primary learning stimulus presented a potent and important opportunity to increase immigrant students' interest in STEM learning. However, transitioning into the academic year's monthly

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club meetings presented challenges in continuity of attendance and therefore retention of conceptual learning. At the WMF, the planned opportunities for student sharing of STEM experiences and learning with the public and families were daunting. UBEATS staff found that most children retreated and preferred not to participate in this typical mode of scientific exchange. Girls, particularly, while enthusiastically engaged in UBEATS activities throughout Year One, avoided individual participation in public events at the WMF.

During UBEATS Year One of the AY club meetings, the Burroughs Wellcome Fund's standard student evaluation surveys were used and produced results asynchronous to the UBEATS staff observations. Questions were raised whether the standard survey data collected during the camps and monthly meetings captured an accurate picture of the children's learning, attitudes, and future thinking. After reviewing the language of the surveys in that context, UBEATS and BWF staff agreed that adjustments were needed for this population. Focus groups were increased and during surveys, staff could clarify meanings for the children, and that surveys may need to be read aloud to individual students, and as needed, to explain the intent of a question.

UBEATS staff Year One reviews of the children's progress identified perceived challenges to the children's future opportunities in STEM learning and careers. These included weak family support, lack of self-confidence, fission/fusion social behaviors undermining collaboration, and confusions about American cultural expectations and opportunities. [NOTE: 'fission/fusion', a concept from animal behavioral sciences, describes fluid/changing alliances that occur often and impact relationships and outcomes.] As noted in research of STEM education and culturally diverse immigrant communities:

> In many societies, cultural norms prioritize respect for teachers and other adults as authoritative sources of knowledge. In other words, validity of knowledge is often based on the validity of its source, rather than the validity of knowledge claims. Children who are taught to respect the wisdom and authority of their elders may not be encouraged to question received knowledge in ways that are compatible with Western scientific practices or normative school science (Lee et al 2005).

While the UBEATS students journaled regularly, observations revealed that they preferred alternate, non-verbal means reliant on other intelligences to convey comprehension of their STEM learning. Drawing, gestures or dance movements, music-making, rapping, imitating sounds, and finding correlations to sound environments beyond UBEATS programming signaled untapped opportunities for these children to convey STEM learning.

Considering both the challenges and opportunities, UBEATS staff proposed a new learning design -science translation - as an intervention that could use the children's innate funds of knowledge with their acquired UBEATS STEM learning to counter the significant impacts of cultural, economic, and developmental differences. A science translation intervention employing children's theatre techniques was planned to assist with broadening and strengthening STEM learning, and support STEM identity and self-efficacy.

Year Two: Method and Rationale

YEAR TWO: Activities conducted in the second year utilized non-traditional STEM methods to engage UBEATS participants, comprised of both returning students and new arrivals, in thinking about, learning, and conveying STEM knowledge through the process of science translation. Using a targeted goal of producing a collaborative student-centered and created staged theatrical production to convey to families and the public the relevance and meaning of science, the study tested this method as a possible intervention to build STEM self-efficacy. By engaging student interest in using observation and listening skills, technology, and critical argument, students explored how to reinterpret science as valid story. This new approach leveraged Year One data showing that the UBEATS population, while interested in science (81.8%), was also thinking about jobs in arts and entertainment (54.5%). The data also showed that the children thought UBEATS helped them learn science better (63.6%) and helped them feel better about learning science (72.7%). However, more than half did not see science's relevance to everyday life (54.6%). Thus, the planning for UBEATS Year Two summer camp and its successive AY club activities focused on developing an alternative pathway, the translation of science knowledge, to leverage creativity - a critical aspect of science research- and provide multi-modal opportunities for students of diverse cultural and

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ethnic backgrounds to personalize and express STEM learning and its relevancy while engaged in collaborative research.

Year Two: Methods

All of Year Two's learning activities centered on science translation as the impetus for student research activities, analytical thinking, and abstract planning. Building on the students' previous research of sound environments, animal husbandry and communication, they were tasked with creating, making, and presenting STEM concepts through the medium of puppetry. This active, learner-centered process employed a hands-on, makerspace approach that challenged students to examine scientific questions in detail, take and defend perspective, and make sense of science's impactful role on life.

We hypothesized that: 1) this generative process of science learning and translation could imbed a creative, collaborative, and maker approach to STEM learning; 2) the process of dynamic engagement among and between children could heighten scientific discourse that would deepen the STEM experience; and 3) the creative process of shared commitment to inquiry and collaboration, aligned with STEM knowledge creation, could develop a path to STEM self-efficacy.

The methodology focused on the children developing story lines to engage audiences in the science of three specific animal species, selected by the children from resident species at the GSC, that they had ongoing access to and had engaged with during Year One. Mentored by a children's theatre professional, the children focused their research of sound's impact on behavioral, communicative, and husbandry sciences as the basis for story creation, character development, sounds and sound tracks, costuming, scenery, and eventual performance. This process began during the 2015 summer camp and included a field trip to a professional puppet company where the children explored representation, allusion, and movement – elements continued during UBEATS AY club meetings.

Children chose three species for story development and self-selected to join an animal's team - 'tigers' or 'gibbons' or 'penguins' - making themselves experts, keeping detailed records of their research, and translating their knowledge of that animal to others. Learning activities were designed to support the authenticity of the developing story lines through questioning, debating, and reviewing scientific facts, and by increasing STEM knowledge of the three chosen species' behaviors, sound environments, conservation, and sustainability issues at the GSC and in the wild. Using observation skills, recording ambient and focused sounds, interviews with animal caretaking staff, and behind-exhibit observations, the students engaged as scientists to incorporate the complexity of sound's influence on animal behavior, survival, and well-being.

As students demonstrated little to no prior experience or knowledge of puppetry, drama, and mask work, students were first exposed to examples of each of these before being asked to apply their STEM learning outcomes. During the Year Two summer camp, students experimented with making puppets from every-day found objects. Working in small groups, they created simple story narratives using common household objects to explore how creative and imaginative work is accessible with no previous experience. Additionally, videos and pictures of professional productions combined with the summer camp's field trip to the professional puppet company provided students both the opportunity to experience professional manipulation of puppets and masks and first-hand physical manipulations with those objects. These activities further challenged the children to explore and compare the physics of movement in humans and animals while generating excitement about creating their own puppets and stories.

This translational process generated science narratives during UBEATS AY club meetings that revolved around two major drama-in-education practices: 1) create a student-centered environment that places students in-role as the expert; and 2) through exploratory generative activities, develop students' ideas, STEM knowledge and inquiry, and empathetic responses to an animal's behaviors, perspectives, and environmental needs.

This process requires a balance between input of both Learning Leader and students—a "flexible framework" that works to build on children's ideas. Such a supportive environment affords children the safety to "make a bridge for them[selves] between their own experiences of the world and the meaning of the drama, so that both insight and understanding arise from the activity." (O'Neil & Lambers, 1982, p. 10). To this end, games and activities that leveled the power dynamic between Learning Leader and student

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simultaneously engaged and supported student cognition and its physical expression and encouraged inquiry-based learning to help students more accurately represent their animal's story, thereby building agency.

Second, the students' generative processes were supported and guided by the noted drama pedagogue, Constatin Stanislovski's, concept of what if—a phrase that is fundamental to all learning and that serves to jettison unnecessary imposed parameters or limitations. What if is used "as a lever to lift us out of the everyday life on to the plane of imagination." (Stanislavski, 1989, p. 59). Prompts, such as "what if 'you' [role playing as your animal] were to encounter a predator", were used to propel students into scenarios that engaged their knowledge of animal behavior and communication, and environmental issues while stimulating explorations of their animal's options and possible actions. Students generated scientifically grounded problems that their animal might encounter and the individual, group, and environmental options available to resolve them. They were challenged to define what their animal might 'want' using their STEM knowledge, and what was stopping their animal from achieving the objective. This process built the framework for the students' improvisations in-role as their animal.

Each group's narrative and major characters encompassed story-telling's basic protocols of antagonist, protagonist, and supporting characters. Through a guided design process, students began construction of representational puppets, masks, and habitats. Similar to the children's first introduction to puppetry, each animal group's characters and scenery began with simple materials that demonstrate puppetry's accessibility: cardboard, craft paint, and jersey knit fabric from recycled t-shirts. To increase family participation and interest, additional efforts at local community centers engaged parents and families in scene construction and costume building.

The role of sounds and sound-making in animal behavior, for survival and in environmental soundscapes, was the key provocative element for the narratives. Hence, the students focused on defining and representing the sounds that corresponded to their story. Each narrative's soundtrack was integrated as live Foley sounds made by the students, and as recordings that the students made of themselves, and/or through found sound files.

For the capstone performance of Year Two's Wild Music Festival, and to further emphasize the role of sound for the public and family members, audiences were asked to provide additional story-telling sounds cued by card prompts using icons instead of English words. Audience-provided sounds combined with the planned soundtracks to integrate environmental and animal noises critical to the telling of each story and were rehearsed with the audience just prior to each animal's puppet story performance.

Planning and Coordination of UBEATS Activities. The progression of the children's STEM learning around important information about their animals' sonic environments and behaviors with their evolving stories shaped the second-year's curriculum. The interdisciplinarity of the instructional team provided important, critical resources for the design and implementation of the programming and activities. The team's expertise in BioMusic, STEM education, theatre education, music education, ELL learning, and technology instruction helped shape resources in three areas - species education, story building and puppetry, and research of sound and/or music – anticipated and generated activities that supported the goals and objectives of the study's plan including the integrated scaffolding of unified learning sequences. Building on UBEATS first-year concepts and knowledge, relevant new information and activities were incorporated in the learning strategies to leverage conceptual learning across the continuum. Technology continued to play a significant role not only as a learning tool but with added importance for layering the sonic dimension into soundtracks for the puppet shows. Students used iPods to record the show's targeted species at the GSC and some of the sound effects eventually used in the shows. Additionally, sound recording apps were sourced to learn and review sound terminology, such as pitch/frequency and patterns, within the context of each animal's environment and communication frequency range of hearing and sound-making. Embedded multimedia played through a smart board helped students understand the complexity of their animal's habitat and the prey/predator relationships in those sonic habitats.

Throughout UBEATS programming, learning activities included building expertise in contextual knowledge and explicit but differentiated academic vocabulary used in different disciplines, specifically

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music, science, or technology. Student learning evolved collaboratively and competitively and was reinforced using appropriate scientific methods to inform all multi-modal learning contexts. This process provided multiple but meaningful ways for diverse learners to participate and to convey STEM knowledge to peers and staff.

The final capstone event, the second Wild Music Festival, at the GSC featured two performances of three student-designed, student-created, and student-performed puppet shows in a theater setting; one presented for their families and one for the public. By performing their science translations as a collaborative team, students invested in the quality and success of their team's storytelling and its performance, often advising one another about how to improve the performance while engaging in conversations about the meaning and importance of their animal's story.

Discussion

The second-year data suggest that the goals and objectives set for immigrant ESL and ELL children in STEM programming can be addressed in non-traditional, alternative ways. First, UBEATS wanted to know if these children developed STEM knowledge, expertise, and self-efficacy through the process. Results show (survey results in supplemental materials) that 60% to 80% acquired complex understandings of the integration of animal behavior, animal communication, environmental factors, and issues related to conservation and sustainability. Further, the children developed and relied on a suite of fundamental scientific process skills to address questions about their animal including:

- observation 75%
- recording 66%
- writing about 56%
- reading about 50%
- searching the internet 41%

Finally, key impacts of UBEATS programming included positive attitudes:

- about science (77% yes, a lot or yes, a little)
- about using science process skills (77%)
- about interest in animals (82%)
- interest in nature (88%)

UBEATS experiences also changed:

- ideas about what scientists do (84%)
- student perceptions of improved technology skills (84%)

All represent significant outcomes for building STEM self-efficacy.

Conclusions

This 2-year case study pursued alternative methods centered on employing diverse learning styles and multiple intelligences for culturally and linguistically diverse students. Specifically, non-traditional methods that exploit communicative behaviors served as a means to build STEM self-efficacy, identity, and learning in children who typically underperform in traditional classroom environments. In an innovative interdisciplinary and progressive cycle of learning activities, students acquired, used, and relied on STEM skills and academic vocabularies of multiple disciplines to realize a larger goal, a learning output they designed and performed for a valued audience. This learning design promotes students' communication of their understanding of STEM concepts while practicing skills and arguments used by scientists.

The larger arc and format for these learning outcomes capitalized on integrated, interdisciplinary multi-modal STEM content and a science translational process and performance. This approach leveraged non-verbal communication systems important to multiple fields of science, to the arts, and to sports but underrepresented in most academic learning environments. Its timeline allowed multiple accommodations for the Learning Leaders by providing: 1) adequate support for planning and preparation; 2) multiple sessions of cross-talk that developed an integrated team perspective.

For the children, self-efficacy in learning is understood to be central to enabling participation in the STEM pipeline. Research repeatedly shows that student self-efficacy, or a student's belief about their ability to be successful in a specific domain, is strongly related to "internal beliefs and experiences (that) combine to influence their ideas and expectations about their own capabilities with respect to STEM" (Dorsen et al, 2006). But recognizing oneself and others as capable, valuable, and competent in STEM remains an allusive outcome particularly for these children who typically receive disappointing performance feedback, experience educational inequities, grapple with cultural norms regarding expertise, and generally fade into the

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background or disappear when it comes to finding a voice in the formal or informal classroom (Betz & Hackatt, 2006; Johnson-Ahorlu, 2012; Lent et al, 1994). The prevailing challenge remains how to stimulate young minds in ways that enable immigrant children to change preconceptions about their abilities and futures in STEM, while leveraging initial interests in science and curiosity about the world. To counter and restructure these cultural and conceptual patterns, UBEATS explored alternative methods and pathways for these children to think about, process, and participate in science learning.

Traditional approaches to STEM learning for immigrant students often channel activities grounded in vertical thinking outcomes - those associated with learning rules and right/wrong correlated choices. By suspending judgment and allowing multiple versions and rearrangements of information, the UBEATS students came to rely on their expertise, science knowledge and research, as well as their science processing skills while negotiating collaboration and innovation. This restructuring of the learning environment amplified opportunities to reinforce the value of inquiry on multiple levels in a re-imagined makerspace. Thus, by encouraging generative thinking, UBEATS students experimented with concepts and processes that challenge limiting parameters, categories, classifications, and labels, eventually finding new relevance in creating substantive translations of the science.

Learning research confirms multiple valid pathways to learn, think, and communicate science. The UBEATS intervention designed and tested a novel science translation method for diverse cultural and linguistic students using multiple intelligences in generative inquiry processes to expand how learning, thinking, and 'doing' science can take place. By enabling these children to develop a 'voice' within a STEM learning context, they controlled their success and science became fun and relevant to them and their families. The outcomes suggest that these positive experiences provide personal relevancy, increased STEM interest, and engaged future thinking about STEM - all critical elements for building self-efficacy in STEM.

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Dr. Pat Gray directs UNCG's BioMusic Research Initiative. Her latest project is UBEATS, a program that brings students to STEM through a focus on music and nature.

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Supplementary Materials Include:

Participant Surveys, Years 1 & 2
Survey Results
Figure 1. Participants by Country of Origin
Figure 2. Participants by Gender
Figure 3. Participants by Grade Level

A New Paradigm for STEM Learning and Identity in Young Immigrant and English Language Learners: Science Translation As Interdisciplinary, Multi-Modal Inquiry

SUPPLEMENTAL MATERIAL

1. Surveys Results – Year 2

Findings from Survey
Spring 2016
Figure 1: Percentage of Students Who Reported Engaging in Specific Science Behaviors in Relation to the Animal They Studied

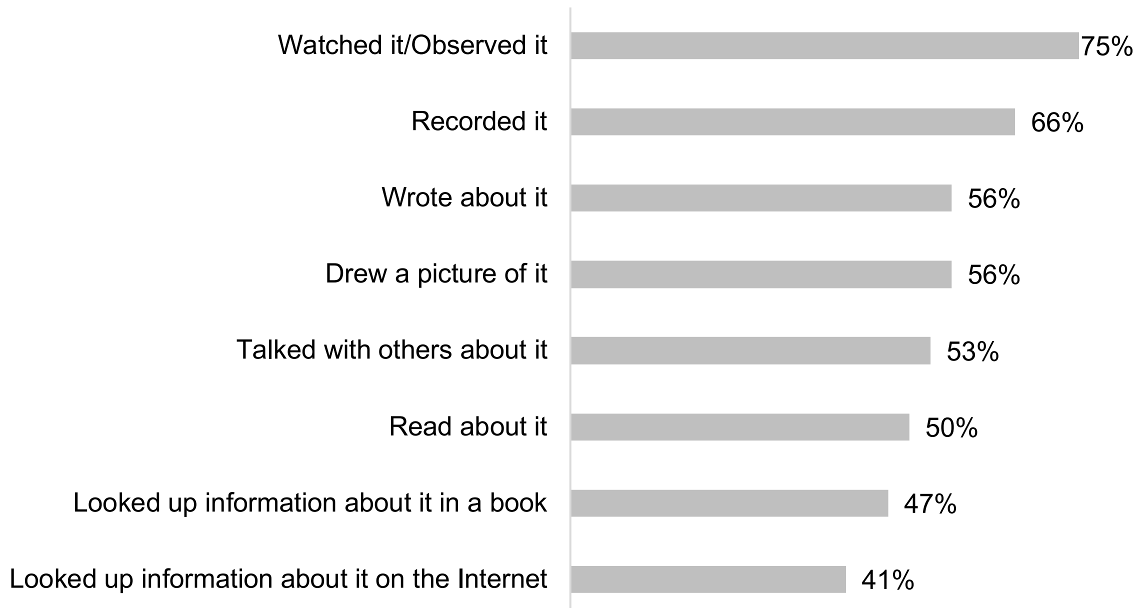


Figure 2: Students' Self-Identification of Their Knowledge Level of Their Animal Relative to Their Friends Not at UBEATS

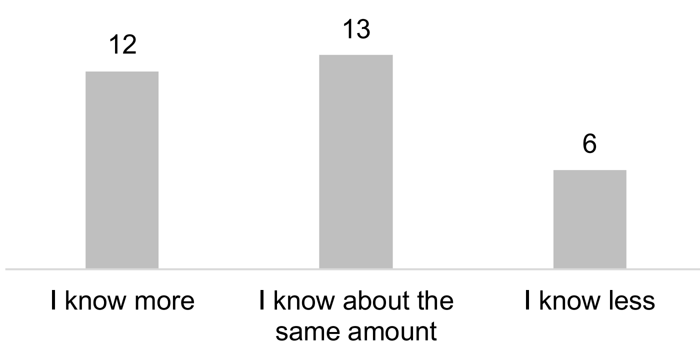


Figure 3: Degree to Which Students Indicated That Being a Part of UBEATS Had the Following Impacts

[Scale: Yes - a lot (3), Yes - a little (2), Not really (1)]

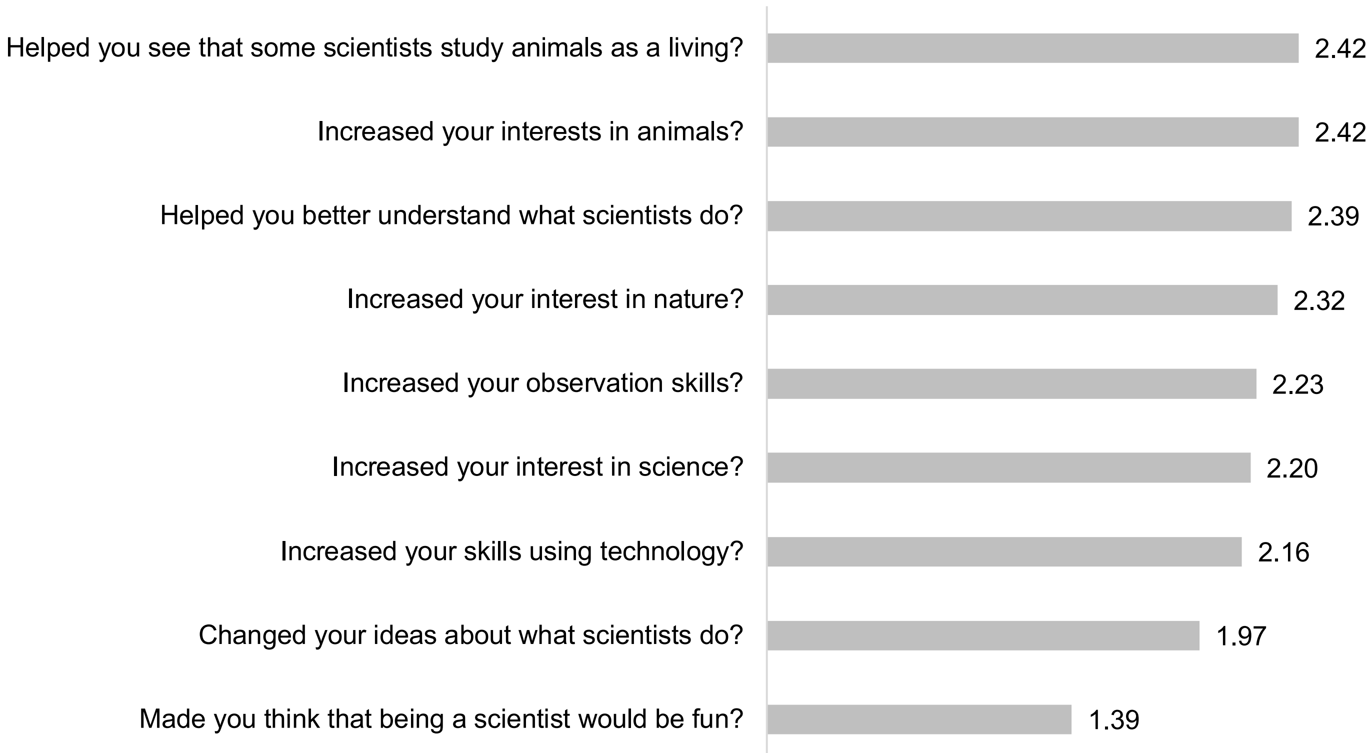
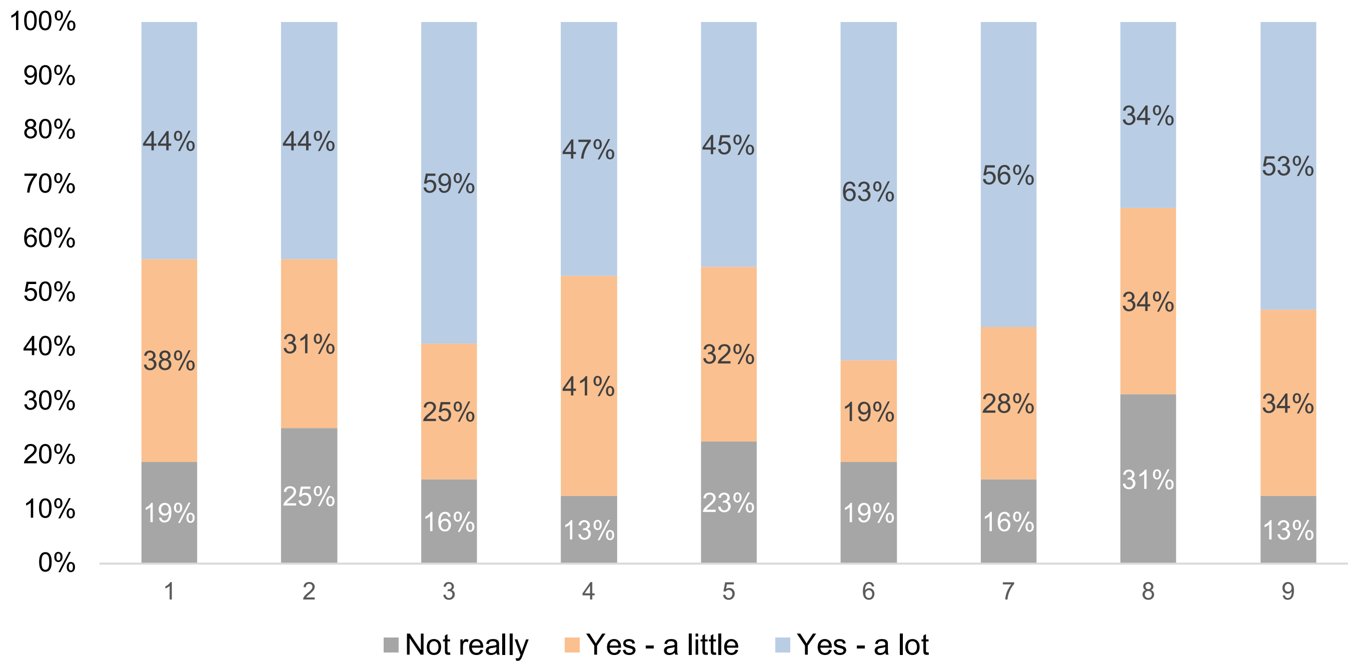


Figure 4. Bar Chart of Survey Results



Student Survey Questions

(Survey to be read out loud)

1. You have been studying different animals as part of the PROGRAM this year. Please indicate what you know about your animal by filling in the chart below.

My animal is:
My animal eats:
My animal lives in:
Other animals that also live there are:

My animal uses sound to:
The sound my animal makes is:
Dangers to my animal in the wild are:

2. Are there any other things that you can tell people about related to your animal?____

3. When scientists want to learn about an animal, they may do many things such as those listed below. Which of the things did you also do to learn about your animal?

Watched it/Observed it	Talked with others about it
Looked up information about it in a book	Recorded it
Wrote about it	Looked up information about it on the Internet
Read about it	Drew a picture of it

4. Do you think you know more, about the same amount, or less about your animal than your friends who are not at UBEATS?

I know more	I know about the same amount	I know less

5. Has being a part of UBEATS:

a) Increased your observation skills?	Yes, a lot	Yes, a little	Not really
b) Increased your skills using technology?	Yes, a lot	Yes, a little	Not really

c) Increased your interests in animals?	Yes, a lot	Yes, a little	Not really
d) Increased your interest in nature?	Yes, a lot	Yes, a little	Not really
e) Increased your interest in science?	Yes, a lot	Yes, a little	Not really
f) Helped you see that some scientists study animals as a living?	Yes, a lot	Yes, a little	Not really
g) Helped you better understand what scientists do?	Yes, a lot	Yes, a little	Not really
h) Changed your ideas about what scientists do?	Yes, a lot	Yes, a little	Not really
i) Made you think that being a scientist would be fun?	Yes, a lot	Yes, a little	Not really

Findings from Survey

Spring, 2016 (n=32)

Table 1: Number and Percent Providing Correct Responses

	Gibbon (n=14)	Penguin (n=10)	Tiger (n=8)	Total (n=32)	Percent
My animal lives in:	11/14	9/10	7/8	**27/32**	84.4%
My animal eats:	9/14	9/10	8/8	**26/32**	81.3%
Dangers to my animal in the wild are:	10/14	8/10	6/8	**24/32**	75.0%
The sound my animal makes is:	10/14	6/10	7/8	**23/32**	71.9%
My animal uses sound to:	6/14	6/10	8/8	**20/32**	62.5%
Other animals that also live there are:	3/14	10/10	6/8	**19/32**	59.4%
Additional information about my animal:	5/14	5/10	6/8	**16/32**	50.0%
Total:	**54/98**	**53/70**	**48/56**	**155/224**	69.2%

Percent:	55.1%	75.7%	85.7%	69.2%

Sample Responses

Other animals that also live there: Penguin Seals, fish, shrimp, orcas, lions

My animal uses sound to: When baby is come, Talking to each other, Danger is coming, Trouble is coming, Communicate with their parents and friends, To find another tiger

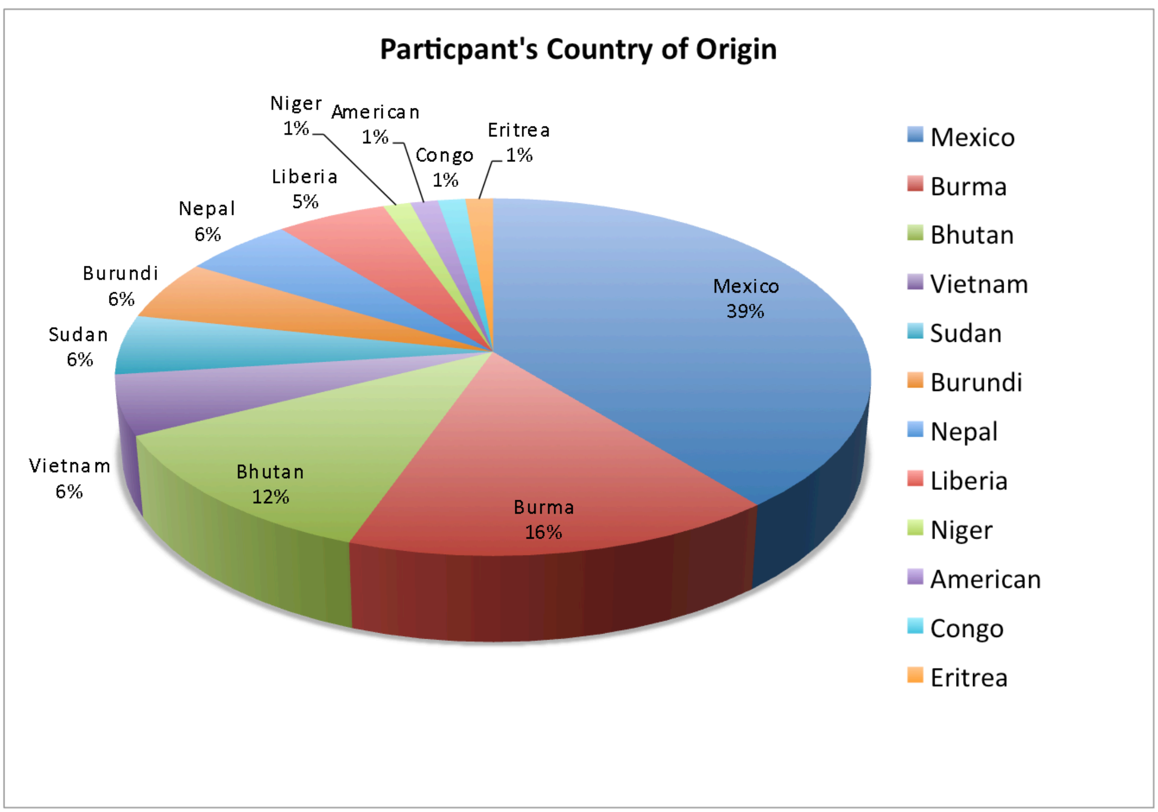
The sound my animal makes: High and low pitch, A loud sound, Donkey sound, Owl sound, Roar, Chuffing

Dangers to my animal in the wild are: People because they cut the trees, People hunting them, Whale, Leopard seals, orca, and sharks, Lions

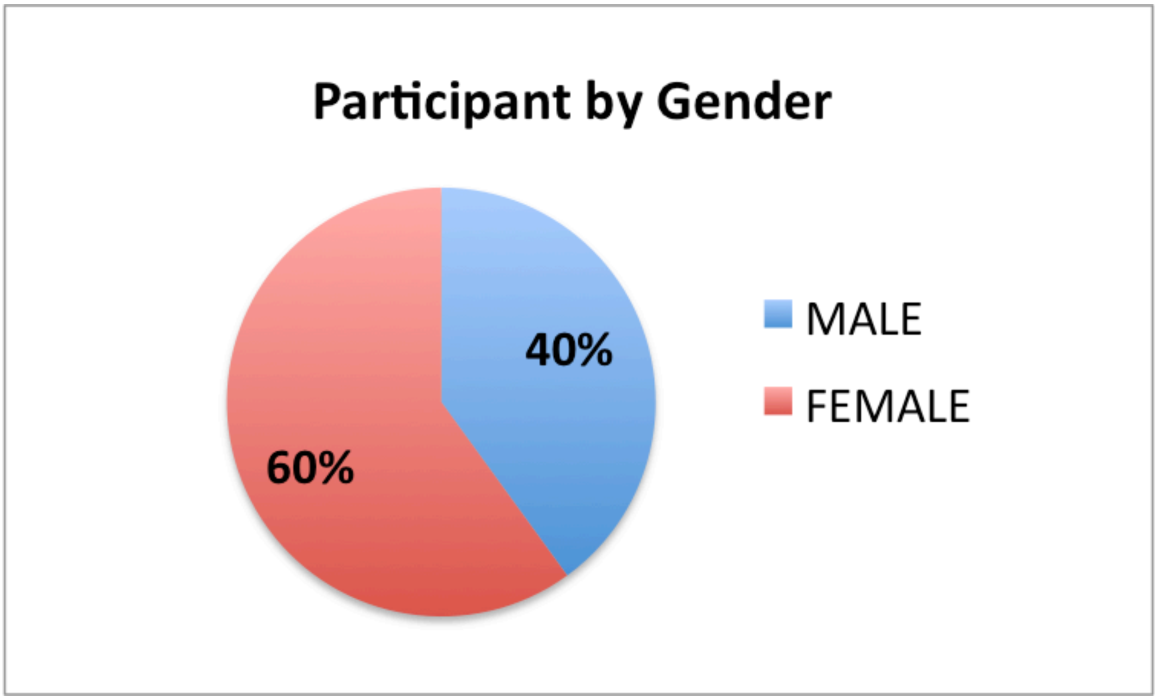
Additional information about my animal: A lot of people think the gibbon is a monkey but it is not because gibbons don't have tails; They look like little real kids. They eat using their hands. They climb trees; Brown fur, they have families, live in zoos; The mom and dad take turns taking care of the baby while one parents searches for food; I can tell them that penguins are very protective creatures, and they use guarding and going to find food strategies; They climb trees; My animal runs from danger or hides; They are very good. They like to eat meat and chicken.

Figures 5a, b, c. PROGRAM Participant Demographics

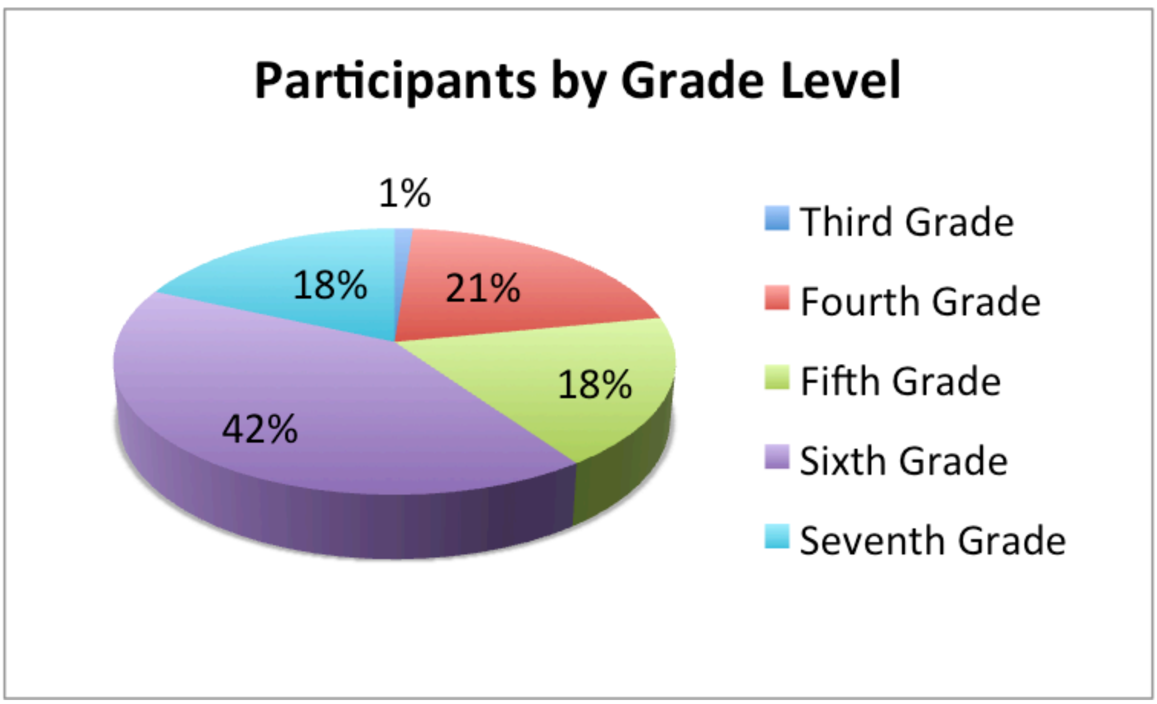
a. Country of Origin



b. Gender



c. Grade Level



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