A Summary of Inclusive Pedagogies for Science Education[1]

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Abstract

In this paper, we offer a brief review of six pedagogical and theoretical approaches used in education and science education that we grouped as inclusive pedagogies. Though not an exhaustive list, these pedagogies are more commonly used in educational research and have commonalities, yet are distinctive in some ways. They collectively contribute to making science teaching and learning more inclusive to a broader population of learners, such as students from diverse cultural, linguistic, and social backgrounds and students with physical and learning differences who have traditionally been marginalized in learning science. Furthermore, these inclusive pedagogies aim to decrease educational inequities and raise the level of academic rigor and access for all students. Finally, we discuss ways these inclusive pedagogies can be extended to address reform efforts in science education.

Inclusive Education: An Umbrella Term

Inclusion is a philosophy based on social justice that advocates for equal access to educational opportunities for all students regardless of difference (Loreman, 1999). Inclusive education as a broad field involves students from a wide range of diverse backgrounds and abilities learning with their peers in school settings that have adapted and changed the way they work in order to meet the needs of all students (Loreman, 1999). Historically, inclusion focused on students with disabilities with the goal for their education to be educated in the least restrictive environment, according to the *Education for All Children Act*, or Public Law 94-142. Overtime, the term inclusive/inclusion has changed in meaning and intent to address a broader application of educational opportunity for all students. If we engage in a contemporary or broader view of inclusive education, the description offered by Liasidou (2012) is very appropriate for science education to consider:

> Inclusive education reflects values and principles and is concerned with challenging the ways in which educational systems reproduce and perpetuate social inequalities with regard to marginalized and excluded groups of students across a range of abilities, characteristics, developmental trajectories, and socioeconomic circumstances. Hence, inclusion is inexorably linked with the principles of equality and social justice in both educational and social domains. (p. 168)

However, Slee and Allan (2001) stated, "[w]e are *still* citing inclusion as our goal; *still* waiting to include, yet *speaking* as if we are already inclusive" (p. 181, original emphasis). We have yet to meet the social justice aims for all students.

For inclusion to meet its social justice intentions, Slee (2011) stated, "inclusive school cultures require fundamental changes in educational thinking about children, curriculum,

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pedagogy and school organization" (p. 110). Hence, the onus of change does not reside with children and their families to transform an educational system that has not been receptive and respectful of their cultures, identities, languages, literacies, and communities; the system itself needs to change and adapt to increasingly diverse learners in today's classrooms, schools, and society. We also argue the same for science education and the need to adapt to the changing demographics that schools are experiencing. Therefore, to adhere to the philosophy of inclusion and to utilize inclusive pedagogies, science education as a field will have to change, requiring institutional and structural change at multiple levels. Ware (2004) stated that to be inclusive, we have to identify and remove all barriers that hinder student learning. This means increasing participation for all students who are experiencing inequities in education.

Hence, the six pedagogical approaches presented below are framed under the larger umbrella of inclusive pedagogies because they promote educational access for all students. We suggest these six pedagogies as they are common in education and divided them into two broad categories: culture and identity (culturally relevant pedagogy and culturally responsive pedagogy), and language, literacy, and community (cultural congruence, funds of knowledge, third space, and culturally sustaining pedagogy). These inclusive pedagogies might initiate a conversation toward social justice and inclusion for students of color, or students from diverse cultural, economic, ethnic, linguistic, racial, and religious backgrounds. Descriptions, definitions, and examples in science education research and other content areas are discussed.

Culture and Identity

In this first set of inclusive pedagogies, understanding culture and identity are key to teaching and learning for students of diverse backgrounds. The pedagogies focus on cultural diversity and discuss the important role teachers play in knowing who their students are as well as themselves in order to meet the needs of diverse students in classrooms.

Culturally Relevant Pedagogy

The first inclusive pedagogy is culturally relevant pedagogy. Gloria Ladson-Billings (1995b) discussed that culturally relevant pedagogy originated in anthropological work focused on the disparity between children's home or community culture and school culture. Culturally relevant pedagogy also grew out of social justice roots that advocated for the success of African American students. Ladson-Billings discussed the significance of language and cultural congruence, appropriateness, and compatibility in education and argued that a streamlined focus on student-teacher language does not do enough to address the needs of urban education or African American youth. Therefore, she proposed that culturally relevant pedagogy function as a pedagogical practice as well as a theoretical framework that "not only addresses student achievement but also helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools (and other institutions) perpetuate" (p. 469). Ladson-Billings explained that teachers who practice culturally relevant pedagogy are producing: (a) "students who can achieve academically," (b) "students who demonstrate cultural competence" and (c) "students who can both understand and critique the social order" (p. 474). The framework of culturally relevant pedagogy is most valuable when teachers aim to produce all three qualities in the classroom simultaneously and create a learning environment where all students succeed academically without sacrificing, compromising, or devaluing their cultural

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identities as they engage in social change and agency. Culturally relevant pedagogy has been used broadly in education (Aronson & Laughter, 2016), including mathematics education (Timmons-Brown & Warner, 2016), English education (Lopez, 2011), and social studies education (Milner, 2014). Next, we consider culturally relevant pedagogy as consisting of two foci— a focus on the teacher and a focus on the student.

Culturally Relevant Pedagogy for Teacher Practice

Culturally relevant pedagogy focuses on the teacher. This includes three important elements: how teachers view themselves and others; how they view knowledge; and how they structure social relations within the classroom (Ladson-Billings, 2006). First, a culturally relevant teacher must have a strong sense of self and a strong sense of community to enact culturally relevant pedagogy. As a result, teachers see teaching as a way to give back to and build their communities, while seeing all students as capable of reaching high academic expectations. In the classroom, teachers view and treat students as experts with important knowledge and invaluable experiences. Second, a culturally relevant teacher is concerned with how students view knowledge. The teacher sees knowledge as socially constructed and views knowledge critically. Teachers build students' skills through content and activities that allow them to better understand and critique their social position and context. Third, a culturally relevant teacher believes in creating flexible student-teacher relationships that are equitable, empowering, and reciprocal.

To illustrate the work needed in developing culturally relevant teachers, we offer examples from science teacher professional development and science teacher education. Through this work, we better understand and visualize the propositions of culturally relevant teaching focused on the teacher (Ladson-Billings, 1995a). First, in teacher professional development, Johnson (2011) examined the transformation of teachers as they progressed along the continuum of culturally relevant pedagogy. By exploring the experiences of two middle-school science teachers, the researcher considered practices that build upon: (a) teacher conceptions of self and others, (b) teacher structured social relations, and (c) teacher conception of knowledge. Johnson illustrated successful progress along the culturally relevant continuum through practices in a science classroom, such as employing daily challenges, experiments, and investigations for the students and setting clear, high expectations for all students.

In addition, Johnson (2011) noted that culturally relevant teachers can be expected to create classroom discussions that encourage students to think critically and to analyze their role in science. Teachers who practice culturally relevant teaching valued opinions, funds of knowledge, and student-generated ideas within science discussions. Culturally relevant teachers can be expected to make concerted efforts to become part of the community by coaching or mentoring other teachers and students in learning science. Johnson featured a characteristic of a culturally relevant teacher as social activist, one who can make a change in the sociopolitical worlds of students. Finally, the culturally relevant teacher can be expected to feel a sense of responsibility for creating opportunities for students and encouraging them to create future opportunities for themselves. Ultimately, the culturally relevant teacher was able to reflect on her or his identity within the community in order to "build social structures that supported student learning", develop a "student-driven collaborative learning community", and provide students with the tools they need to "navigate social inequities" (p. 194).

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Second, in teacher education, Mensah (2011) argued that in order for preservice teachers (PSTs) to teach in culturally relevant ways, they too must learn and engage in culturally relevant pedagogy for themselves. In presenting three assertions that connect to the tenets of culturally relevant pedagogy, Mensah asserted that (a) PSTs must have collaborative support with diverse others in making connections and developing practices to teach science, such that they "experience academic success" (Ladson-Billings, 1995a, p. 160), not only for themselves as teachers but also for their students; (b) PSTs must use a language that allows them to elicit student roles that will empower students to want to do and learn science; this includes ways to engage students in the knowledge, language, and skills of science-- formally (in school) and informally (at home)-- and to make personal connections to science. The goals and content for teaching science must be educationally beneficial, such that PSTs "develop and/or maintain cultural competence" (p. 160) for the students they teach; and finally, (c) PSTs must also include their personal interests and reasons for teaching science content. The goals and content for the science lesson must also be culturally and personally relevant and focus on real-world connections, such that PSTs "develop a critical consciousness through which they challenge the status quo of the current social order" (p. 160) for themselves and their students through science. Within their science methods course, the PSTs collaboratively planned, taught, and assessed a Pollution Unit in a 4th-5th grade classroom that identified environmental racism as an issue in their community. In planning and teaching the unit, PSTs and students learned about the health effects associated with air pollution within their community. Mensah concluded that PSTs need sufficient opportunities to teach and assess their growth and development as culturally relevant teachers in positive, collaborative, supportive teacher education programs so that their science curriculum and teaching incorporate the tenets of culturally relevant pedagogy.

Culturally Relevant Pedagogy for Student Learning

Second, culturally relevant pedagogy also focuses on student learning with an aim toward social justice. Culturally relevant pedagogy differs from other culturally sensitive or responsive approaches in its criticality or purpose to interrogate and disrupt the status quo (Parson & Wells, 2011). There are several studies in science education that highlight the critical consciousness aspect of culturally relevant pedagogy with aims for social justice.

For example, in an AP chemistry course, Morales-Doyle (2017) introduced justice-centered science pedagogy as a theoretical framework built on the traditions of culturally relevant pedagogy and critical pedagogy in an urban neighborhood high school. The students were supported to succeed academically while taking up urgent issues of social and environmental justice issues they identified in their communities. The students studied soil contamination caused by a closed coal plant in an area predominantly populated by people of color. The students in the study conducted a series of science investigations such as measuring the concentrations of lead and mercury in neighborhood soil samples, studying the various chemical reactions associated with coal mining and coal combustion, and acid-mine runoff. They presented the results to the community, including their parents, teachers, and peers. Morales-Doyle reported that the curriculum organized around environmental racism supported academic achievement and provided opportunities for students to position themselves as transformative intellectuals who demonstrated complex thinking about science and social justice issues. Students were supported to develop critical consciousness about environmental racism, hypersegregation, and economic inequality. Both academic achievement and critical

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consciousness allowed students to think in complex ways about scientific knowledge, social justice, and community. Thus, a social justice-centered science pedagogy involved all elements of culturally relevant teaching.

In another example of culturally relevant pedagogy and critical consciousness, Mallya, Mensah, Contento, Koch, and Barton (2012) focused on student learning in the development of a curriculum where seventh-grade students living in high poverty areas of New York City participated in the Choice, Control and Change (C3) science curriculum. Data were collected from eight case study students and analyses revealed that students were able to extend their C3 science understandings beyond the classroom door by developing and expressing science agency in 1) critically analyzing the conditions of their food environment, 2) purposefully making healthier choices, and 3) expanding the food and activity options available to themselves and others. The idea of “food desert” or having limited healthy food options in their neighborhoods and not being “tricked” by food advertisements that entice them to eat foods that are not healthy for them were ways the youth became more conscious of inequities and challenges in their food environments. From participation in the C3 curriculum, science content, and learning activities, the students began to view their worlds with a more critical mindset and devised ways to transform conditions for themselves and others. Based upon the curriculum and findings from the study, the researchers proposed taking a closer look at creating meaningful and relevant learning opportunities for students through connecting school science with issues of personal and social significance in students’ lives outside of school.

Culturally Responsive Pedagogy

The second inclusive pedagogy is culturally responsive pedagogy. Similar to culturally relevant pedagogy, culturally responsive pedagogy rose out of “concerns for the racial and ethnic inequities that were apparent in learning opportunities and outcomes” (Gay, 2010, p. 28) that were brought to light with the rise of multicultural education. Culturally responsive pedagogy emphasizes teaching diverse students through their ethnic, linguistic, racial, experiential, and cultural identities. Culturally responsive pedagogy “validates, facilitates, liberates, and empowers ethnically diverse students by simultaneously cultivating their cultural integrity, individual abilities, and academic success” (p. 46).

In addition, Gay (2014) identified two major pathways to culturally responsive pedagogy. The first is primarily pedagogical and the second is curriculum. Both encompass the heart of culturally responsive pedagogy as teaching to and through the cultural strengths of diverse students. Gay offered a description of practices that utilize students’ cultures in the learning process. However, teaching in these ways requires a change in teaching methods, curricular materials, teacher dispositions, as well as relationships that extend within and outside the school and community. Thus, culturally responsive pedagogy, according to Gay, requires a learning context, classroom climate, student-teacher relationships, instructional techniques, communication, and caring as characteristics that will promote learning for diverse students.

Culturally Responsive Pedagogy as Practice through Curriculum

There are examples of culturally responsive pedagogy through teaching practices and curriculum development projects. In a recent metasynthesis of 52 empirical articles, Brown (2017) explored the ways in which culturally responsive pedagogy appears in science teaching practices. She summarized the culturally responsive classroom through the Culturally Responsive Instruction Observation Protocol (CRIOP). The culturally responsive classroom: a) develops meaningful classroom relationships; b) seeks family collaboration; c) formatively assesses students to showcase multiple forms of understanding; d) promotes diverse experiences and real-world experiences in the curriculum and learning environment; e) fosters student engagement; f) values multiple discourses; and g) employs a sociopolitical lens for all students. Brown noticed that "aspects of inquiry most often used to advance culturally responsive science education included *Obtaining, Evaluating, and Communicating Information... Constructing Explanations and Designing solutions...*and *Developing and Using Models"* (p.1159). Among the instances highlighted by Brown, student collaboration, student experience, student co-construction of Western science and Indigenous Knowledge, and student sociopolitical connections were trends most prevalent in a successful culturally responsive science classroom.

Moreover, Brown and Crippen (2017) conducted a study with six high school life science teachers as they learned to enact culturally responsive pedagogies from participating in a professional development program. The teachers changed their views of students, repositioning students as leaders with authoritative knowledge and as constructors of knowledge and artifacts from engaging in science. The teachers also experienced community building to promote interaction, learning, and student voice. Although there was enactment of culturally responsive pedagogies, the researchers noted that teachers needed to make more connections to families' fund of knowledge and to develop critical sociocultural consciousness within the curriculum they taught.

As another example, the Alaska Science Consortium in collaboration with the Alaska Rural Systemic Initiative, teachers, Elders, Native community leaders, agency personnel, and educational consultants have been working on developing culturally responsive science curriculum (Stephens, 2001). The production of a curriculum handbook effectively integrated Indigenous and Western knowledge on various science topics. The handbook featured four areas for developing culturally relevant science curriculum, which are cultural relevance, best practices, state standards, and assessment. In addition, the handbook provided teachers with a curriculum that has "current pedagogical principles that move educational practice from teaching *about* culture as another discrete subject to teaching *through* the local culture as a way to bring depth, breadth and significance to all aspects of the curriculum" (p. 5). The author showed how to involve Elders in the classroom and pointed out topics of cultural significance that incorporated local knowledge with science standards. Overall, the handbook highlighted what cultural relevance might look like in curriculum design and practice.

Culturally Responsive Pedagogy and Interdisciplinary Teaching

There are many examples that extend culturally responsive pedagogy as curriculum in other content areas that science education might gleam insights. For instance, the Big History Project (BHP) is an interdisciplinary curriculum founded on the work of David Christian (2011). The BHP curriculum integrates science and social studies among other disciplines including the arts, English language arts, and business to engage students in the human experience. The curriculum includes origin stories, and collective learning plays a central role in a students' understanding of social studies and science. Throughout the curriculum, there are thresholds curated with multimedia educational resources and tools to discuss the details of origin stories, rich cultural histories, and the role humans play in the history and future of Earth. This inclusive

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curriculum values thinking critically about the globalized impact of humans in the past, present, and future. In summarizing the "big history" of Earth, BHP calls on students to examine their own roles in global concerns.

Language, Literacy, and Community

In the next set of inclusive pedagogies, language is introduced as a central part to teaching and learning for students of diverse backgrounds. These inclusive pedagogies still focus on cultural diversity and identity; now, these areas relate the importance of home, school, and community connections through the development of language and learning.

Culturally Congruent Instruction

First, cultural congruence is most associated with the work of Au and Kawakami (1994). They noted that cultural congruence

> …does not mean an attempt to replicate a home or community environment in the classroom. …Culturally congruent educational practices incorporate features of the students' home culture but do not result in activities and environments identical to those of the home. (p. 6)

Parsons, Travis, and Simpson (2005) defined culturally congruent instruction as instruction that "addresses the mismatch between institutional norms and values and those of the homes and communities of ethnic minorities" (p. 187). The aim of culturally congruent instruction is to incorporate in schools and classrooms the home and community cultures of children (Au & Kawakami, 1994).

Lee and Fradd (1998) in their work introduced instructional congruence as the intersection of developing language and science literacy. They explained that the work of Au and Kawakami (1994) helped shape their framework of instructional congruence. However, Lee and Fradd recognized that cultural congruence could serve as a means for teachers and students to communicate and understand each other in the science classroom. They claimed that there is a greater need for developing language skills in the process of fostering scientific literacy in the classroom. Thus, Lee and Fradd adapted cultural congruence to better suit the needs of science education and to provide a stage that intersects science and literacy. The resulting instructional congruence leads to "language development and science learning" (p. 18). The intersection requires that teachers value both the nature of science and the cultural and linguistic experiences of students. Teachers therefore must foster language building through cultural, linguistic, and science experiences.

Recent research has highlighted ways in which culture and language can be nurtured in the science classroom. Palinscar, Symons, and Schleppegrell (2013) worked with 26 teachers and 12 coaches/resource teachers in helping bilingual Arab American children in grades 2 through 5. With most of them classified as English language learners, the researchers investigated how Functional Grammar Analysis might assist students in science literacy. Using pre- and post-writing assessments, the children increased their range of ideas and explanations as well as writing and learning from science texts.

Community and Cultural Networks

Further work in science education expanded this notion of science and literacy to include congruency between classroom, home, and community cultural practices (e.g., communalism). Such congruency often alters the context or the classroom environment in order to lessen the cognitive load students need to engage in science. Community cultural practices might be thought of as the development of supportive networks of people in the success of students of color in science. For example, students of color developed fictive kinship relationships to support their resiliency, perseverance, and success in college physics (Alexados, Jones, & Rodriguez, 2011). It was their support, motivation, care, and trust that allowed the students to develop friendships and serve as role models to achieve in physics. In their relationships, the students talked physics which extended beyond the college classroom into their personal lives.

Similarly, in mathematics education, Walker (2006) examined how students' existing worlds and their compatibilities and incongruencies were reflected in academic communities that supported and facilitated their mathematics achievement. The 21 high-achieving male and female, African American and Latina/o mathematics students in Walker's study attributed their success to many reasons, namely family members other than their parents, their "near peers" (p. 64) within their family, such as cousins and siblings, and "fluid relationships" (p. 65) with close friends, peers, and classmates. It was a combination of supports that assisted students in their mathematics achievement and the development of communities of support.

For cultural practices that promoted positive classroom learning environments for science learning, Olitsky (2007) investigated interaction rituals in an eighth-grade urban magnet school. The study focused on teacher practices that fostered high levels of emotional energy, feelings of group membership, and sustained interest in science. The researcher concluded that successful interaction rituals fostered interest in science topics that previously might have been less motivating to students' interests and that a community of practice model in the classroom also contributed to successful science learning.

Finally, Parsons et al. (2005) conducted a study using Black Cultural Ethos (BCE) as an approach to learning contexts with eighth-grade students. For the African American students in particular, they experienced enhanced achievement in culturally congruent contexts that were aligned with their preferences. In addition, when BCE was viewed as "a repertoire of practices acquired through prolonged participation in a cultural community" (p. 194), the African American and Euro-American students indicated a preference for BCE when instructional conditions used communalism, verve, and movement in the classroom learning environment.

Therefore, the work in science education, and mathematics education, that builds upon cultural congruence has at its core rich linguistic styles that come from strong relational and cultural communities that should be used in creating meaningful classroom learning environments. Cultural congruence includes having flexible classroom arrangements that allow for collaboration and high expectations for learning through language. Au and Kawakami (1994) stated, "Successful teachers appear to be those who have respect for the language students bring from the home and community. They provide culturally congruent instruction by capitalizing upon students' existing language ability to meet school goals" (p. 17).

Funds of Knowledge

A second area that focuses on language, literacy, and community is funds of knowledge. Funds of knowledge emerged out of the qualitative work of teacher-researcher collaborations with families of students living on the United States-Mexico border. Funds of knowledge, as described by Moll, Amanti, Neff, and Gonzalez (1992), are the valuable understandings, skills, and tools that students maintain as a part of their identity. Moll et al. further explain that funds of knowledge are “a single aspect of a broader, multidimensional research project: teachers as co-researchers using qualitative methods to study household knowledge, and drawing upon this knowledge to develop a participatory pedagogy” (p. 139). Families have funds of knowledge from everyday life, such as fixing cars, working in a business, or building homes that are overlooked by teachers and the school community. Thus, funds of knowledge are explained at the intersection of household knowledge and classroom knowledge that can be used as valuable resources in the classroom. The teacher can be seen as the mode through which “strategic connections” (p. 132) can be made between the outside world and the classroom. The role of the teacher is to solicit and incorporate students’ funds of knowledge in the classroom.

For example, the findings reported by Barton and Tan (2009) highlighted the use of funds of knowledge and Discourse that a teacher supported in his science classroom. Barton and Tan conducted a design experiment in a low-income urban middle school, sixth-grade classroom. They wanted to support the science teacher in incorporating pedagogical practices that were supportive of students’ everyday knowledge. While conducting the study, the researchers noted how the students interacted with a food and nutrition curriculum and identified the different funds of knowledge and Discourse the students brought into the classroom. The researchers offered funds of knowledge threads and how these contributed to the creation of hybrid spaces in school science. The funds of knowledge threads considered family and ethnic traditions for funds of cooking and sharing food; community funds and peer culture funds, such as solidarity, fashion, and television. Barton and Tan also found that students participated more when the teacher actively elicited the students’ various funds of knowledge. Students had new ways of engaging in science that promoted academic achievement and inclusion. For instance, the researchers saw how one female student who was not previously engaged and one male student who routinely got in trouble for misbehaving or not completing assignments were participants in the classroom through active engagement in activities and discussions when funds of knowledge were shared in the classroom.

In an ethnographic study by Wilson-Lopez, Mejia, Hasbun, and Kasun (2016), they examined the relationship between engineering cultural practices and the funds of knowledge found in Latina/o adolescents’ familial, community, and recreational settings. Using engineering design processes, the seven groups of Latina/o youth identified and addressed problems in their communities. The researchers found the youth’s everyday skills and knowledge from familial, community, and recreational settings aligned with systems thinking, reasoning, knowledge production and processing, communication and construction tools, scientific and mathematical knowledge, and teamwork. As an example of funds of knowledge related to recreational activities, youth talked about watching and reading popular television shows and books that gave them insights into engineering practices. One engineering design project students completed to address a question and concern from one of their classmates, Sofia, was to redesign an enclosure for her Chihuahuas. The authors stated, “participants held funds of knowledge that were relevant to engineering design processes, bodies of knowledge, skills, and habits of mind. While in their homes, communities, and recreational settings, the participants addressed complex real-world problems” (p. 300). In order to solicit students’ funds of knowledge for engineering, the teacher administered a survey to her students. The information gleaned from student interest surveys was helpful in actively connecting and positioning students’ funds of knowledge and expertise to engineering.

Teacher within Community

Furthermore, funds of knowledge are embedded within a social network that places close family and friends in the role of the "teacher." The role of teacher as a part of the family and the role of student as part of the educational community are not unique in diverse communities and households. For this reason, the family-teacher and student-teacher system should be used as a model for teaching and learning. In this relationship, there has to be an element of trust between the teacher and the students. For example, Upadhyay (2006) conducted a study with a White elementary teacher in an urban school setting. The teacher, along with students who bring different funds of knowledge from their lived experiences, integrated her life experiences and those of her students into her teaching. During a classroom discussion of food as part of the curriculum used in the study, Upadhyay described how the teacher talked about what she had heard on the radio about baby foods and how "food scientists" have discovered why certain kinds of baby food might not be good to feed to babies before a certain age. She also talked about her own experiences with her children and how she nourished them. By integrating her life experiences, students opened up and engaged more in the science lessons and started sharing aspects of their lives. Students commented to the researcher liking the opportunity "to share their ideas, experiences, and knowledge in class because it made them feel included" (p. 106).

Teachers have to become familiar with communities and how they view science and include their knowledge and resources in learning science. Teachers also have funds of knowledge of community for teaching. As an example, Goldston and Nichols (2009) used photonarratives to re-collect memories of community and cultural referents from middle school Black science teachers in the south. The teachers used this information to evoke funds of knowledge and to develop cultural relevancy in science teaching for their students. All the teachers had grown up in the local southern communities and used their knowledge of their communities and their experiences to explore cultural referents and to make connections to their students for instructional scaffolding. One example was using Black literacy traditions, such as oral speech performances and the participatory language of the Black church, with the language of science. Both types of discourse were used and respected in the science classroom.

Recently in the literature, Borgerding (2017) highlighted the successful integration of local funds of knowledge into an evolutionary biology unit in a rural high school. In the classroom, the science teacher was able to build trusting relationships with students by valuing their funds of knowledge while discussing complex science concepts presented in the evolution unit. The teacher honored local "rural" funds of knowledge as local knowledge of nature and treated students' religious knowledge as a form of local expertise as they studied evolution and other related concepts. In particular, the students respected the teacher's apparent neutrality, sensitivity toward multiple positions, explicit attention to religion and evolution ideas, and transparency of purposes for teaching evolution. The researcher talked about the level of trust and rapport the teacher built with students prior to teaching the evolution unit. Knowing that students had to negotiate very different worldviews, the students appreciated their teacher's fair and caring approach regarding the sensitive religious matter and science content in the teaching the unit.

Funds of Knowledge across Different Contexts

A general review of the literature showed funds of knowledge research in different subject areas and across different contexts. For example, Dabach and Fones (2016) argued for recognizing immigrant youth's transnational funds of knowledge and how a high school social studies teacher created space for one Pakistani student who returned to his country of origin. Having a wider vision of citizenship-building for immigrant students' transnational experiences, the teacher supported a more inclusive learning environment and society for his students.

Second, through a case study in Vietnam, both international and local researchers foregrounded local funds of knowledge through teacher-parent partnerships and challenged beliefs and assumptions teachers had about families, their backgrounds, and knowledges (Hedges, Fleer, Fleer-Stout, & Hanh, 2016). The teachers were able to build more reciprocal relationships and greater insights into the existing funds of knowledge held by families and communities than previously known.

Finally, Hogg (2016) noted the inequitable school experiences for Māori and Pasifika students in New Zealand. By applying funds of knowledge in a New Zealand high school, the teachers, students, and parents participated in the study and all learned how to incorporate funds of knowledge to support academic learning and achievement gains, which were reported by all participants.

Third Space

The third inclusive pedagogy we introduce for language, literacy, and community is third space. Due to merging of family, home, and community with school, students' funds of knowledge are often used in creating a third space; in other words, funds of knowledge and third space are often spoken together. Moje, Ciechanowski, Kramer, Ellis, Carrillo, and Collazo (2004) explained that their works draws from critical and social theories, such as hybridity theory, or the "in-between" (Bhabha, 1994, p.1), called the *third space* (p. 36). Moje et al. explained: "Hybridity theory connects in important ways to third space, because third spaces are hybrid spaces" (p. 42). Based upon the work of Bhabha and others, three current views of third space are outlined by Moje and her colleagues-- hybrid space as a supportive scaffold that links traditionally marginalized funds of knowledge and Discourses to academic funds and Discourse; hybrid space as a navigational space in gaining competency and expertise to negotiate differing discourse communities, such as the disciplinary discourses of specialized content areas; and finally, hybrid space where different funds of knowledge and Discourses coalesce to destabilize and expand the boundaries of official school Discourse, creating a space of cultural, social, and epistemological change where competing knowledges and Discourses come together in "conversation" with each other.

Taking up third space and funds of knowledge, Moje et al. (2004) conducted a study with 30 middle school students in a predominantly Latino/a, urban community in Detroit. The researchers investigated the types of literacy practices used in the various funds of knowledge and Discourses students had. They explained that the integration of knowledges and Discourses were drawn from different spaces in the construction of "third space" that merged the "first space" of students' home, community, and peer networks with the "second space" of the Discourses they encountered in more formalized institutions such as work, school, or church. Though they acknowledged the first and second spaces were arbitrarily labeled, the point was "that these spaces can be reconstructed to form a third, different or alternative, space of knowledges and Discourses" (p. 41). The researchers collected and analyzed data on when and

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how students and teachers brought various funds to understand classroom texts in the generation of a third space.

Two particularly interesting findings were that students did not volunteer their knowledges drawn from home and that students drew upon knowledges they gained from families, communities, peers, and popular culture. In the context of the students' interviews, when asked, students enthusiastically shared everyday, family, community, and peer knowledges. For the student participants, the third space had to be actively developed by including many different communities, along with the local space, for students to engage in experiments, reading, writing, and discussions. The second finding was that youth drew upon many different funds outside of school such as families, communities, peers, and popular culture. These spaces represented different sources of knowledge, ways of knowing, and connections to scientific literacy that when prompted by the teacher added richly to the learning environment. The researchers concluded, "We see these hybrid spaces as moments where science is no longer a separate world as students learned to display competent and meaningful scientific literacy in applying scientific knowledge to their local communities and their daily living" (p. 70).

Third Space for Participation

Gutierrez, Rymes, and Larson (1995) discussed the importance of third space as a platform upon which students and teachers can examine and challenge the social structure within their classroom community. The authors described the systemic devaluing of the student voice where students were disempowered through the monological discourse of the teacher. Gutierrez and her colleagues point out that students were not asked to participate in a dialogue within the class and so the classroom became "scripted." The script of the teacher was authoritative and placed little to no positive value on student voice. As a result, students developed a counterscript in order to navigate the power structure of the classroom. The counterscript was manifested in two ways-- disruption and internalization. The counterscript was displayed as misbehavior, jokes, cultural references, or disregard for teacher feedback. Furthermore, the counterscript became an internal process of resentment and psychic violence. The third space therefore was the only place within the classroom to have communication building between teachers and students. This negotiated middle ground was where learning occurred. Third spaces, therefore, are especially important in science education as teachers navigate their roles as gatekeepers by allowing students to participate in science classrooms in their own ways.

In a similar way, Quigley (2013) explained that third space merges home and school, and within the third space, there is a balance in the roles and voices of the teacher, home, and students in the classroom. In her research study, Quigley examined the ways in which teachers created a third space in the science classroom by integrating community, family, and scientific discourses throughout science units. For example, the kindergarten teacher highlighted in Quigley's study was able to construct a third space in her all-girls' science academy classroom by inviting community members to participate in science curriculum units. The members of the classroom community were parents and grandparents. Their role was prioritized in the classroom and helped to create a space for the girls to feel comfortable experimenting and using the language of science. In the classroom, there was mutual respect and common goals shared between the teacher and community members for "merging discourses" (p. 854) so that the first space of home and the second space of science came together in creating a third space for learning. Parents also continued to help the girls at home in learning science, positioning the community members as the science teachers at home. By doing so, the teacher was not the only science teacher for the girls, and science learning did not occur only in school.

Similarly, by designing a third space in the mathematics classroom, students engaged in mathematics using objects and manipulatives that specifically related to their lives. For instance, Lipka, Sharp, Adams, and Sharp (2007) designed a mathematics course that integrated the indigenous knowledge and cultural backgrounds of students. Students were able to view mathematics through the lens of their cultural identities. In the third space created by the mathematics teachers in this case, students' cultural competence was also valued and fostered. Teaching mathematics through references to cultural landmarks, objects, and beliefs excited students learning and participation in the third space created in the mathematics classroom. Consequently, third space research in science education, and other subjects, bridged two worlds in the generation and construction of a new space for teaching and learning. In the third space, student participation was heightened.

Culturally Sustaining Pedagogy

In this fourth and final inclusive pedagogy, Django Paris (2012) proposed the term culturally sustaining pedagogy, arguing that educators needed a change in stance, terminology, and practice because it is possible to be relevant or responsive to something without ensuring its continuing presence in students' repertoires of practice. He constructed the framework on the shoulders of culturally relevant pedagogy, culturally responsive pedagogy, funds of knowledge, and third space frameworks. Paris explained that culturally sustaining pedagogy fosters "linguistic, literate, and cultural pluralism as part of the democratic project of schooling" (p. 93). He made the argument that culturally sustaining pedagogy is a necessary pushback against monocultural and monolingual social constructs perpetuated by education. He argued for a stance that "support[s] young people in sustaining the cultural and linguistic competence of their communities while simultaneously offering access to dominant cultural competence" (p. 95). The culturally sustaining pedagogy stance may be used to push students to understand and value their culture, language, and funds of knowledge while also navigating the dominant culture. In sum, culturally sustaining pedagogy has an explicit goal to support "multilingualism and multiculturalism in practice and perspective for students and teachers" (p. 96).

Weiland (2014) examined ways in which science learning environments can be transformed to foster culturally sustaining experiences in informal settings. In this study, a group of eight, recently immigrated Latin American mothers to the US were observed with their children at a science center. The mothers were later interviewed to gather their understanding of their experiences in the science center with their children and to learn how science centers can provide culturally sustaining experiences for first-generation families. Though the mothers were unfamiliar with museums and informal institutions, they felt the science center helped in supporting their socio-cultural ways of knowing and interacting with their children. From the study, researchers can learn much about creating culturally sustaining science learning environments that can be: a) welcoming of diverse learners, b) culturally and linguistically accessible to culturally diverse students and participants, and c) nurturing of cultural science experiences shared by students and families. The mothers shared their desire for resources to be in Spanish so they could take full advantage of the science center. In addition, a suggestion of bilingual signage could help to navigate the space and allow them to learn English vocabulary. Even better, signage with scientific terminology in Spanish could also help them learn English and develop knowledge in science content. The mothers felt the signage was important to build biliteracy for them and their children. The mothers' suggestions for providing multilingual resources (e.g., video of exhibits), colorful décor, images of diverse views of science, and programs to orient people to the center would all be helpful in making them feel welcomed. Not only did Weiland state the importance of bringing in diverse community members in the design of museum programs, other researchers have suggested similar cooperative models of engagement in museums and science centers (Feinstein & Meshulam, 2014).

In another example, Tolbert (2015) used culturally sustaining pedagogy to reflect on "issues of power, language, culture, and pedagogy in the classroom" (p. 1331). In her study with preservice and beginning teachers, who served both indigenous and non-indigenous students, Tolbert was interested in knowing how mentoring conversations brought about culturally sustaining practices for them as science teachers. Tolbert discussed that mentors and teachers can implement culturally sustaining pedagogies by "deconstructing racism, facilitating relevance (valuing funds of knowledge, student experiences, and sharing power in science learning opportunities), building and sustaining relationships, and attending to instructional complexity (allow students to "co-construct science knowledge" (p. 1351). From analysis of video-recorded classroom observations of culturally sustaining pedagogy, Tolbert also looked for instructional moves or actions that were inconsistent with culturally sustaining pedagogy. From her analysis of data, including mentoring conversations, Tolbert proposed a framework for culturally responsive mentoring that incorporated four key themes related to the nature and content of mentoring conversations: deconstructing racism, facilitating relevance, building and sustaining relationships, and attending to instructional complexity. She concluded that more attention should be given to how novice and veteran teachers can be simultaneously mentored to attend to issues of cultural sustaining and reform-based practices.

Summary of Inclusive Pedagogies

In sum, the inclusive pedagogies offered above have many things in common, though they are unique in their own way. First, when considering the broader focus of inclusion (Liasidou, 2012), the six inclusive pedagogies share a common focus on enhancing the educational engagement of all students, and students especially from diverse cultural, linguistic, and social backgrounds as well as students with physical and learning differences; however, for this last group, students with physical and learning differences, limited studies address this area so explicitly in the science education literature for inclusion. Hence, more work is suggested for in this area.

Second, the notions of culture, identity, language, literacy, and community are common among the approaches presented. In many ways, they build upon each other and offer ways of engaging students who have been marginalized in education and science opportunities. The pedagogies insinuate a hope and vision for students to see themselves and their communities reflected in the classroom, language, and content taught in school science. Thus, science education will have to support teachers to develop knowledge and skills to incorporate these inclusive pedagogies and to create instructional activities that engage culture, identity, language, literacy, and community. Even "reform-based" practices in science might have to change toward equity approaches (Windschitl & Stroupe, 2017) to ensure that students' skills and knowledges they bring to school are utilized in the classroom and are connected back to everyday experiences. Immediate and long-term success in science will position students to contribute meaningfully in a democratic society where deep understandings of science supports personal goals and aspirations.

Third, the approaches aim to decrease educational inequities and to raise the level of academic rigor and access for all students. To do this, there is a focus on teachers making change, adaption, and modification to current teaching practices and curriculum to incorporate what students and communities have as valuable knowledges for learning, such as funds of knowledge, and using these knowledges in the generation of new learning spaces, such as third space (Moje et al., 2004). The notion of funds of knowledge, third space, and culturally sustain pedagogy invoke a broader community of engagement in learning and invites an extended network of who is seen as a teacher and knowledgeable other in the classroom. How teachers construct a new classroom environment that allows the bridging of school, home or community is critical to inclusive education. Thus, the overall aim for educational equity encompasses these inclusive pedagogies.

Potential for Inclusive Pedagogies in Science Education

According to Rodriguez (2015), a significant improvement of the Next Generation Science Stands (NGSS) (NGSS Lead States, 2013) from the previous version of science education standards is the combined effort to more directly address issues of equity and diversity. Still, Rodriguez's critique of the NGSS document is that it needs to be "more culturally and socially relevant" (p. 1042). With the "add-on" of the case studies and Appendix D, which talks about equity issues in the Conceptual Framework and NGSS document, the importance of attending to culture, identity, language, literacy, and communityof diverse students can be read as "not as important" (p. 1044) within these documents. The "*one* place" (p. 1042, his emphasis) for teachers, administrators, science educators, and researchers to get examples of inclusive pedagogies, except for the added Appendix D, is a missed opportunity for equity.

To address this need, Rodriguez (2015) proposed a framework of *engagement, equity and diversity* through sociotransformative constructivism (sTc), a theory of teaching and learning where teachers and learners dialogically and critically (re)construct knowledge in culturally and socially relevant ways (Rodriguez, 1998). He illustrated an example of what science education could look like through *engagement* where content is tied to everyday experiences; *equity* where accommodations make the classroom accessible to parents; and *diversity* where students are able to tie their cultural and ethnic backgrounds to activities and discussions in class (see Table 3, p. 1043 for more examples). The inclusive practices presented in this paper support the framework of *engagement, equity, and diversity* that Rodriguez proposed.

The potential for inclusive pedagogies to address issues of student learning, academic achievement, and educational change has to occur at several levels. Change has to be a concerted effort, extended over time to support teacher education and teacher professional development that is also challenged by accountability and policy initiatives that hinder science teaching and student learning (Carlone, Haun-Frank, & Kimmel, 2010; Rodriguez, 2010). Teachers alone cannot solely be responsible for addressing fundamental issues of educational equity for all students. All must be on board, from local to state to national stakeholders.

In our work as teacher educators, we address two primary areas to begin teacher learning about inclusive pedagogies. In the section that follows, we offer additional examples that highlight the potential of inclusive pedagogies for science teacher education and science teacher professional development. Finally, we discuss implications for science content teaching within a broader system of stakeholders interested in inclusive pedagogies in science education.

Teacher Education

For inclusive pedagogies to fulfill the aim of equitable access and social justice goals for all students in science education, this requires work and resources on several levels (Rivera Maulucci, 2010); however, we start with teacher education and teacher professional development. In teacher education, Mensah (2011) used culturally relevant teaching in an elementary science methods course. Three elementary preservice teachers worked together in co-planning and co-teaching a Pollution Unit in a 4th-5th grade science classroom in New York City. Though the study took place in one elementary classroom, the researcher had support from the principal to place preservice teachers in all classrooms in the school. All the preservice teachers in the science methods course created lessons using tenets of culturally relevant teaching and taught their lessons in every classroom in the school. The findings of the study revealed the importance of having supportive collaborations (i.e., teacher education faculty, classroom teachers, the school administration, and preservice teacher peers) in planning, teaching, and assessing students' learning and teachers' implementation of inclusive pedagogies.

The preservice teachers challenged their notions of what science teaching should look like in the elementary classroom and what topics could be covered that would broaden students' and their understanding of culturally relevant teaching and science concepts that connected to their daily lives. The decision to teach a Pollution Unit had personal meaning to the preservice teachers and the students because of high asthma rates and low school attendance. The preservice teachers realized the amount of time and effort necessary in planning and addressing the learning needs of diverse students and teaching science with critical perspectives. Working in a partnership school with support from teachers and administration who placed science as a priority in the elementary school strengthened the potential for inclusive pedagogies.

Teacher Professional Development

Similarly, in teacher professional development, teachers need time with colleagues to create science curriculum materials that allow them to expand content meaning and to implement inclusive pedagogies. One professional development project centered cultural points of intersection for a unit on accelerated motion. Grimberg and Gummer (2013) studied a professional development program for science teachers near or on Native American reservations in Montana. Framed by culturally relevant pedagogy, instructional strategies focused on the intersection of three cultures--tribal, science teaching, and science. The professional development program utilized several inclusive pedagogies. Specifically, culturally relevant pedagogy was used as the conceptual framework; culturally responsive models assisted in the identification of topics relevant to the tribal communities; and culturally congruent instruction guided the design of the activities by determining which tribal cultural elements and practices would be matched to science content. The researchers reported that after two years in the program, the teachers "steadily and significantly increased their confidence in the ability to teach science content and to reach non-mainstream students" (p. 28). The classroom instructional time also increased, allowing students to make connections between science content and topics relevant to their life, communities, and real-world hands-on experiences. The teachers in the study increased their confidence to teach science content and to implement equitable teaching approaches over their two years of participation in the professional development program. Teaching through cultural points of intersection is an example of inclusive pedagogies for teacher professional development that showed both positive teacher and student gains.

Implications and Conclusion

In the previous section, we talk about the potential of inclusive pedagogies for science teacher education and teacher professional development. However, the potential benefits for inclusive pedagogies rest on how teachers implement the NGSS, or teach science content knowledge. With the NGSS (NGSS Lead States, 2013), much of the attention in teacher education and professional development centers on learning about the three-dimensional structure of the NGSS (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014), engineering practices (Cunningham & Carlsen, 2014), learning progressions (Duschl, Maeng, & Sezen, 2011), and argumentation (Henderson, McNeill, González-Howard, Close, & Evans, 2018). Once more, what is often missing is attention to equity and diversity. Instead, attention to how inclusive pedagogies can also be implemented alongside the NGSS to broaden participation for all students in understanding science and engineering practices, core disciplinary ideas, and crosscutting concepts. The NGSS content storylines are useful, but much more can be done in assisting teachers to develop questions that have deeper connections to students' culture and communities.

We contend that focusing on culturally relevant questions might be an approach in teacher education and teacher professional development to support the potential of inclusive pedagogies. For example, preservice and inservice teachers should understand that teaching and learning science content must include diverse perspectives and knowledges. Much of the science content taught in school science does not address issues of equity, diversity, multiculturalism, or social justice. For instance, broad topics and concepts traditionally taught in school science from elementary to high school, such as plants, water, pollution, and electricity can be taught with inclusive pedagogies in mind. If the idea of plants or water were taught in school science, how might these topics be addressed for cultural relevancy: where are plants grown, who has access to organic foods, where are "food deserts" within our communities, is there harm from genetically modified foods? A question of "who has access to clean water" can be taught by studying recent cases from Flint, MI, or Newark, NJ, and extended to study global water crisis with droughts in Somalia, water rationing in Rome, or flooding in Jakarta. Science can be studied to address issues such as, where do you find the majority of pollution producers, how does rising costs of healthcare effect low-income families, what are alternative energy sources for my community?

For inclusive pedagogies to benefit all students, science has to be taught within broader sociocultural, sociohistorical, and sociopolitical contexts that invite multiple perspectives, knowledges, and understandings into the science classroom. These ways of teaching require multi-level support for teachers and schools. The notion of "empowering policies" (Mensah, 2010, p. 982) starts at the local level where success in working with schools and teachers to implement change and reform might occur, and then moves to higher levels, such as district, state, and national-wide policies that support science education through inclusive pedagogies. There are challenges to these approaches (Young, 2010), but science education is uniquely situated to work toward inclusive practices that involve local and national efforts aimed at educational equity for all.

In conclusion, the six inclusive pedagogies shared in this paper can be used to make the NGSS more culturally and socially relevant. Though the pedagogies are distinctive, they share a similar framing in their potential to make science teaching and learning more inclusive to all students, and especially for students who have been traditionally marginalized in science education. With a social justice and advocacy framework to challenge mainstream ways of teaching, these inclusive pedagogies recognize culture, identity, language, literacy, and community as valuable assets in the science classroom. However, in order to teach in these ways, preservice teachers and inservice teachers, with assistance and support from committed stakeholders, will need time and resources to work in collaborative partnerships to address equity, diversity, and social justice in science teaching. Inclusive pedagogies for science education require both policy and administrative decision-making to set structures that will allow these inclusive pedagogies to serve the best interests of all students.

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