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Transformative Transmedia Framework for Early STEM Learners: Harnessing the Power of Science, Literacy, and Media

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The Twin Cities PBS *Ready to Learn* project focuses on the building of science and literacy skills of diverse students ages 5 to 8. It also promotes equity for historically underrepresented children in science (race-ethnic minorities, low-income children with disabilities, English Language Learners). The Transformative Transmedia Framework for Early STEM Learners offers a set of guiding principles that integrate various understandings into one comprehensive framework that informs every aspect of the project. This paper outlines the following: (1) addressing the intersectionality of racial, class, cultural, and STEM identities for young learners and dispel-

ling negative stereotypes; (2) grounding "real world" STEM experiences in the lived realities of diverse learners; (3) recognizing and integrating social and cultural assets in STEM learning experiences; (4) integrating equity within Science and Engineering practices; (5) understanding STEM as literacy; and (6) strategies for integration in multimedia contexts.

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INTRODUCTION

TPT - Twin Cities PBS received funding to create programming and transmedia materials based on a Ready to Learn (U.S. Department of Education, 2016) project entitled *Superhero School: Harnessing the Power of Science, Literacy, and Media*. **The focus of this project is to build the science and literacy skills of diverse students ages 5 to 8 and promote equity for historically underrepresented children in science (race-ethnic minorities, low-income children, children with disabilities, English Language Learners).** Several bodies of literature were used to build a framework that was used in the development of *Hero Elementary*™, a Ready to Learn initiative funded by the US Department of Education. This initiative included TV scripts/episodes for the PBS Kids show, digital learning experiences including digital games and a digital science notebook, hands-on activities, and professional development material for both informal and formal educators. The series involves the diverse students of Mr. Sparks, a quirky and enthusiastic teacher, and his "Sparks' Crew"--Lucita Sky, AJ Gadgets, Sara Snap and Benny Bubbles, who are being trained to become heroes. Together the students work as a team, using their own unique superpowers as well as the "Superpowers of Science" to help people, solve problems, and try to make the world a better place. Specifically, the show's content and transmedia materials were created using an integration of principles from the *Next Generation Science Standards* (NGSS); principles that are embodied in the Corporation for Public Broadcasting's previous *Ready to Learn* work (CPB, 2012), Universal Design for Learning (Meyer, Rose, & Gordon, 2014), and Equity Focused Pedagogy (Joseph et al., 2016; Johnson, 2016). The equity-focused pedagogical framework draws from three theoretical perspectives: NGSS for ALL Students (Lee et al., 2015), Culturally Responsive Pedagogy (Gay, 2010), and The Transfor-

mative Framework for STEM Education (Ellington, 2019). The overall aim of the project is to support interest, engagement, learning, persistence of diverse children (grades K-2) in science, and promote early literacy learning.

TRANSFORMATIVE TRANSMEDIA FRAMEWORK FOR EARLY STEM LEARNERS: AN OVERVIEW

The Transformative Transmedia Framework for Early STEM Learners provides a set of guiding principles that integrate various understandings into one comprehensive framework that informs every aspect of the project. The guiding principles that underlie this framework were derived from a synthesis of literature focused on identity development, equity and diversity in STEM education, culturally responsive teaching, science and engineering practices for early learners, early literacy and English language learning, and the Next Generation Science Standards (NGSS) for early STEM learners. This framework integrates various theoretical perspectives to inform transmedia content development, which includes digital, text-based, multimedia, and real-life spaces and experiences in ways that offers young STEM learners opportunities to engage, explore, play, investigate, collaborate, and make meanings that are personally, culturally, and communally meaningful (Herr-Stephenson et al., 2013). Hence, applying the principles of this framework can provide multimedia learning experiences that promote equity and early engagement in STEM for diverse learners.

The literature on STEM learning overwhelmingly states that identity and identity development are critical to diverse students' interest, pursuit, success and persistence in STEM-related fields (Kane, 2012; Martin, 2012; McGee, 2015; Cook, 2014; Wilson, 2016). Hence, the literature on the intersection of racial and STEM identities was used to inform this framework, in particular how Black and Latinx students' identities influence their interests in STEM, and their decisions to engage in STEM-related pursuits and achieve in these disciplines. We designed this framework to be *transformative*. By this, we mean that the approach to STEM transmedia learning fosters a shift in educators' perspectives from a deficit-based approach to an asset-based approach to STEM learning for diverse students. This shift is internal and lasting, which leads to the transformation of how educators perceive diverse children and subsequently how they approach their work. Further, this shift in perception leads to changes in how STEM education is conceptualized and approached, which will lead to positive learning outcomes for historically marginalized students (Ellington, 2019). This trans-

formative approach helps support and sustain positive STEM identities grounded in the Black and Brown students who are doers of STEM.

In addition to drawing from literature on identity development, we consulted the literature on practices that promote equity and diversity for STEM learners, particularly of Hispnic and Black students. Research shows that although many students live in poverty, a large percentage of these students are Latinx and Black children. According to the US Census Bureau (U.S. Census Bureau, 2012), 21.6% of children in the United States live in poverty, the highest poverty rate since the poverty survey began in 2001. The poverty rate was the highest for Blacks at 38.2% and Latinxs at 32.3%, compared to Whites at 17.0% and Asians at 13.0%. We focused on these learners because the *Ready to Learn* project commits to address the educational needs of students living in poverty (U.S. Department of Education, 2016). Besides, the project focused on how the materials can be used to support English Language Learners (ELL); hence we consulted equity literature specifically focused on Black and Latinx students. This is not to say that other ethnic minority students are excluded from our equity focus; however, for the framework to be useful, we target literature that highlighted the programs and practices that fostered diversity, equity, and inclusion for these targeted populations. The research used to inform this framework was guided by the *Transformative Framework for STEM Education* (Ellington, 2019) and *NGSS for ALL Students* (Lee, et al., 2015).

One of the key bodies of literature consulted for this framework was the literature on Culturally Responsive Pedagogy (CRP). This literature was used to understand the educational practices that promote equity for diverse STEM learners and how these could be applied in a multimedia context (Gay, 2002; Ladson-Billings, 1994, 1995, 2001; Gay, 2002; Villegas & Lucas, 2002). Culturally Responsive Teaching (CRT), Culturally Responsive Pedagogy (CRP), or Culturally Relevant Pedagogy can be defined as using cultural characteristics, experiences and perspectives of diverse students as conduits for teaching them more effectively (Gay, 2002). Although there are many frameworks for culturally responsive teaching (Gay, 2002; Ladson-Billings, 1994; 1995; 2001; Villegas & Lucas, 2002), essential elements of CRT include:

- active learning is encouraged,
- curricular materials and activities are connected to the lives of students, and
- classroom environments are inclusive and interactive (Montgomery, 2001).

One of the central aims of CRT is “empower students intellectually, socially, emotionally and politically by using cultural referents to impart knowledge,

skills and attitudes" (Ladson Billings, 1994, pp. 17-18). This empowerment is achieved through the integration of home and community experiences with school, curriculum, and classroom. These ideas are echoed in *NGSS for ALL Students* (Lee et al., 2015) which identified recommendations that promote success for diverse learners, which include: (1) culturally relevant pedagogy, (2) community involvement and social activism, (3) multiple representation and multimodal experiences, and (4) school support systems including role models and mentors of similar racial or ethnic backgrounds.

As a companion to CRT, the principles of this framework were informed by research conducted under previous *Ready to Learn* grants (Corporation for Public Broadcasting, 2012) and literature on ELL (Hill & Flynn, 2006), and they were integrated in ways that address the needs for Latinx and Black students to use STEM as a vehicle for early literacy and English language learning. It was important that the principles shaping this work were grounded in theoretical and empirical understandings of how students became proficient readers, writers, and thinkers and how this is done when English is a student's second language. In particular, we have chosen several promising practices to ground this framework within best practices for English language learners (Hill & Flynn, 2006; National Academies of Sciences, Engineering, and Medicine, 2017): (1) developing academic language as an integral part of science learning, (2) providing visual and verbal support to help clarify concepts and practices, (3) supporting and encouraging collaborative learning among peers, (4) engaging with students' home language, cultural assets, and cultural funds of knowledge.

The *Next Generation Science Standards* (NGSS)—particularly the Science and Engineering Practices—provided a framework for understanding the core science and engineering content and practices that should shape the content of early STEM learning (NGSS Lead States, 2013). The Science and Engineering Practices reflect the idea that STEM learning should be grounded in the ways that scientists and engineers work (National Research Council, 2012). Students can thus experience for themselves the process of developing scientific knowledge, develop a deeper understanding of how the world works, and connect knowledge across disciplines. Engaging authentically in these practices—actually doing science—helps students see how science can help address challenges facing today's global communities and can drive their interest in continuing their science studies. Also, the Science and Engineering Practices are based on rigorous thinking and communication; they seamlessly merge literacy practices and science. The three primary Science and Engineering Practices that are core to this framework are:

- Asking questions (for science) and defining problems (for engineering);
- Planning and carrying out investigations; and
- Obtaining, evaluating, and communicating information.

These three practices describe the fundamental ways that scientists and engineers do their work. When students engage in asking questions and defining problems, they exercise their voice and agency and can pursue questions and issues that genuinely concern and interest them (Collins, Brown, & Holum, 1991; Torp & Sage, 2002). This often leads to planning investigations to answer their questions and find promising approaches for tackling meaningful problems (Collins, Brown, & Holum, 1991; Torp & Sage, 2002). The practice of obtaining, evaluating, and communicating information is a powerful invitation to utilize both receptive and productive language in a meaningful way. Obtaining and sharing of information are fundamental to the everyday work of scientists and engineers. Whether students pursue STEM careers or not, their lives will require them to obtain scientific and technical information, determine the meaning and value of information, and communicate information to others (National Research Council, 2012). Besides, these two secondary Science and Engineering Practices add depth by supporting learners' sense-making:

- Analyzing and interpreting data; and
- Constructing explanations (for science) and designing solutions (for engineering).

Science is, at its core, a way of making sense of the world (Schwarz, Passmore, & Reiser, 2017). These two practices provide structure and support for students to engage in sense-making as scientists and engineers do, allowing students to express their understandings and use those understandings to make a positive impact on themselves and their communities (Ellington, 2019).

The *Transformative Transmedia Framework for Early STEM Learners* was developed to reflect how the project could apply theoretical and empirical understandings to creating multimedia programming, materials, professional development and outreach programs that promote early literacy and STEM learning, equity and diversity in STEM, and provide an integrated equity-centered approach to transmedia programming.

Transformative Transmedia Framework for Early STEM Learners Guiding Principles

The heart of this framework, as shown in Figure 1 below, rests on early STEM learners' identity and how positive STEM identities are cultivated through the use of multimedia experiences.

Figure 1. Transformative Transmedia Framework for Early STEM learners.

These identities are developed and reinforced through students' exposure to equity focused science and engineering practices, real world STEM experiences and STEM as a form of literacies. These identities are supported through a STEM educational approach that is grounded on the social and cultural assets that diverse STEM learners possess and building on these assets in all areas of multimedia content development. Through integrating these principles, multimedia content becomes more equity focused and inclusive, and therefore has the potential to positively impact early STEM engagement and early learning. In the sections that follow, we provide a discussion of the various principles shaping the framework and key literature informing each of them. Then we provide strategies for how this framework integrated into multimedia contexts for the various aspects of *Hero Elementary*. The article concludes with recommendations and conclusions focused on how other multimedia content developers can apply this approach to the development of multimedia content.

Addressing the Intersectionality of Racial, Class, Cultural, and STEM Identities for Young Learners and Dispelling Negative Stereotypes

Numerous scholars who study Black and Latinx students in STEM have used the concept of identity to gain insight into its role in positive student outcomes (Kane, 2012; Martin, 2012; McGee, 2015; Cook, 2014; Wilson, 2016). Although there are many definitions and conceptions of identity (Abrams & Hogg, 1988; Jenkins, 1996; Oyserman, Elmore & Smith, 2012; Oyserman, 2007), identity is broadly conceptualized as one's answer to the statement "who am I?" or the ways in which individuals and groups define themselves, are defined by and relate to others (Abrams, 1994; Hogg & Abrams, 1988; Deng, 1995; Oyserman, 2007; 2008). As stated by Oyserman, Elmore & Smith (2012) "One's sense of self (his or her identity) influences what he or she is motivated to do, how one thinks and makes sense of oneself and others, the actions they take, and their feelings and ability to control or regulate themselves." (p 74). As a result, students possess different types of identities (e.g., social, racial, gender, religious, academic), and they negotiate these different identities within different contexts. Researchers suggest that learner's identities are enacted and shaped by their participation in socially situated practices such as STEM education (McGee, 2015). Hence, central to Latinx and Black students' persistence and success in STEM is an understanding of the types of socially situated STEM practices (community, school-based, classroom) that foster the kinds of identities that will promote their success and persistence and develop STEM programs that help Black and Latinx students identify as competent learners and doers of STEM.

Given that identity is critical to one's interest, engagement and academic choices, our framework is centered on the idea that our work will encourage young Black and Latinx children to develop positive STEM identities that are grounded in positive racial and cultural identities. This means that all the materials and programs created from this project will encourage and highlight how who they are, as Latinx and Black children, and align with what it means to be viable and productive STEM learners. All of the work that we do integrates these students' interests, values, beliefs and ways of knowing and how to see themselves as STEM innovators. The fundamental message that our STEM practices should reiterate to Latinx and Black students is "We are competent and confident lifelong STEM learners, doers and community members. We contribute to our communities through our STEM learning. It is who we are, and we belong here."

Sociocultural factors are central to the learning process and can profoundly influence children's STEM learning and achievement. These factors

may facilitate or hinder students' learning by shaping their identity, motivation, and academic performance and achievement. Negative stereotypes in the classrooms can impact children's ability to learn, retain information, and lower performance. Several studies show that children develop an awareness of racial stereotypes at an early age. Children at six months of age are capable of recognizing race and gender differences (Katz & Kofkin, 1997) and by age 2, preschoolers can categorize people by race, using racial categories to reason about other people's behavior (Aboud, 2008; Hirschfeld, 2008). Race and ethnic stereotypes become apparent in the preschool years (Aboud & Doyle, 1996; Bernstein et al., 2000), and can influence the children's peer preferences (Aboud & Doyle, 1996; Levy, 2000; Van Ausdale & Feagin, 1996), memory (Bigler & Liben, 1993; Levy, 2000), and other social cognitive abilities. Interestingly, compared to white non-Latinx children, Black and Latinx children are more likely to be aware of broadly held stereotypes which can negatively affect their cognitive capacities (Jambunathan, Burts, & Pierce, 1999; Jencks & Phillips, 2011; McKown & Weinstein, 2003; McKown & Strambler, 2009; Murrell, 2002).

Students' endorsement of stereotypes about racial and gender ability within STEM (Bobo, 2001; Nosek, Banaji, & Greenwald, 2002) negatively influences their STEM identity formation by decreasing their STEM-related self-concept, self-esteem (Okeke et al., 2009; Schmader, Johns, & Barquissau, 2004), interest, identification, and participation in STEM (Lips, 1995; Cheryan et al., 2009; Steinke, 2003, 2017; Kessels, 2015; Carli et al., 2016).

Educators and content developers can support children in developing a positive STEM identity by actively challenging racial and cultural stereotypes. Effective approaches include the use of diverse role models and peer support systems (Cheryan, Master, & Meltzoff, 2015; Leaper, 2015; Kessels, 2015), promoting a growth mindset (Dweck, 2008), and helping students develop a sense of belonging through collaborative work (Master & Meltzoff, 2016).

Grounding "Real World" STEM Experiences in the Lived Realities of Diverse Learners

Research on STEM education illuminates the importance of grounding STEM learning in "real world" contexts (Hoachlander & Yanofsky, 2011). Scholars argue that to make STEM relevant to students, learning experiences must promote engagement and foster positive educational outcomes. STEM learning must be grounded in real-life experiences and be presented

in ways that show how science can be used to solve real-world problems (Gay, 2002; Ladson-Billings, 1995; Torp & Sage, 2002; Villegas & Lucas, 2002). These real-life experiences connect to the NGSS Science and Engineering Practices of:

- developing and using models,
- asking questions and defining problems,
- planning and carrying out investigations, through the use of inquiry and discovery-based curricula and instructional practices, and
- collecting, organizing, representing and interpreting data (Gay, 2002; Kolb, 1984).

These practices, scholars argue, make science and related disciplines "authentic" and allow students to use their scientific knowledge and understandings in ways that reflect the actual work of scientists and engineers. One of the guiding principles of our framework is to ensure that STEM experiences, used in our programs and products, focus on making sure that STEM learners see how STEM is used in their daily lives and reflect authentic STEM learning.

To this end, one of the critical principles shaping this framework is not only making sure that STEM experiences are informed by "real world" STEM, but also reflect the lived realities of diverse learners, particularly the lived experiences of Black and Latinx students. The STEM experiences must take into account how Black and Latinx students experience their worlds and communities and reflect how STEM applies to their real worlds, their communities and themselves. This principle reflects an extension of the idea that STEM learning is relevant when it is shaped by student experience and when it reflects the notion that the "real world" experiences of minority students are not necessarily the same as majority students (Gay, 2010; Kolb, 1984). Hence, as we have created the multimedia materials for the project, there has been a need to consider how concepts and ideas in STEM content and engineering practices are representative of how Latinx and Black children experience their world and their ways of knowing. We are guided by the idea that "real world" STEM experiences are not a "generic" and are grounded in a social, cultural, historical and community context; therefore, our framework requires that we situate the STEM content and subsequent materials in ways that reflect how Black and Latinx students experience the world and reflect the various contexts that shape them as unique STEM learners. The message that we send through this principle is that the real-world experiences that Black and Latinx children have within their reach provide opportunities to learn STEM and address their own needs and those of their communities. The fictional children who attend

Hero Elementary will draw on their own cultural and racial experiences as opportunities to "use STEM to save their world" and thereby know that they can contribute to their communities. Hence the models they create to understand their worlds, the questions they ask, the problems they solve, the types of investigations they undertake and the data they collect and analyze are all grounded in the lived realities of Latinx and Black students, not just "real world" experiences in a generic sense.

Recognizing and Integrating Social and Cultural Assets in STEM Learning Experiences

A growing body of literature highlights the role of social-cultural capital in students' success and persistence in STEM-related fields (Cegile & Settlage, 2014). For the past five decades, the social and cultural capital literature has been used to understand students' ability to succeed and effectively navigate schooling (Thirutnurthy, Kirylo, & Ciabattari, 2010) specifically STEM education (Cegile & Settlage, 2014; Stolle-McAllister, 2011). Unfortunately, the discourse in this area has focused on the "lack" of social and cultural capital that Blacks and Latinxs have given the "negative plight" of these communities (Gándara & Contreras, 2009; Sattin-Bajaj, 2011). The social and cultural capital discourse is generally framed in ways that forward a deficit orientation of Latinx and Black students and their communities. However, there is a growing body of scholarship in STEM that is focusing on an asset-based view of Black students' community and social resources; this literature highlights ways to empower Black students in STEM by understanding the myriad of parental, community and personal resources that they bring to their STEM learning and illuminating how we can draw on these resources to improve educational outcomes for Black students (Ellington, 2016; Ellington & Fredrick, 2010; Harper, 2010; Stinson, 2006). Similarly, the deficit-view discourse of Latinx students can be counteracted by emphasizing the cultural, linguistic, cognitive, social and emotional assets Latinx students bring to the classroom (Garcia & Ozturk, 2018). This assets-based view of social capital asserts that children from all backgrounds are natural learners and doers of STEM; not only can their STEM learning be informed by their community's assets, but they can also give back to their communities through their STEM learning.

Materials and products developed for the project reflect the notion that the children in the episodes draw their "strengths" and superpowers not simply from their innate abilities, but also as a result of the unique social

and cultural assets that are embedded in their communities. As we thought about the transmedia materials, outreach activities and professional development experiences, we took care to place the social and cultural assets of these historically marginalized communities at the forefront of our discussions. The message we send to our audience is that a Black or Brown child does not have to be "exceptional" to engage in STEM learning and that they are already a part of STEM communities and a historical lineage of success in STEM. This approach dismantles the narrative that communities of color or students who come from so-called "impoverished" conditions have to be "special" to do STEM, instead promoting the understanding that their communities have cultivated them to be viable STEM learners in addition to their gifts and talents, all of which are useful in their STEM pursuits

Integrating Equity within Science and Engineering Practices

One of the central ideas embedded in the notion of "equity" is that all students have equitable opportunities to learn STEM, receive high-quality STEM instruction, and are expected to achieve and persist no matter what their race, gender or cultural background is (Gay, 2010). The practices required in science and engineering have been hailed as a key way to ensure that STEM learning is equitable. All learners can engage in these practices since science and engineering are not "culturally specific," and that all students use these practices in their daily lives and their various communities. By emphasizing the Science and Engineering Practices, *Hero Elementary* can support an expanded focus on the contributions of all cultures to the development of innovations and dismantle the idea that only Western cultures have contributed to STEM advances. Also, what counts as science can be expanded, hence shifting our content focus to be more inclusive of students who have traditionally been marginalized in the science classroom and who may not see science as being relevant to their lives or future. By solving problems through Science and Engineering Practices in local contexts, students gain knowledge of science content, view science as relevant to their lives and future, and engage in science in socially relevant and transformative ways (Rodriguez & Berryman, 2002; Torp & Sage, 2002; Lee, Miller, & Januszyk, 2015). Focusing on specific Science and Engineering Practices offers opportunities for "innovation" and "creativity," and can be viewed as relevant to the lives of diverse learners.

Building on this idea, our framework is grounded on the principle that equity is not separate from science and engineering practices, in fact, they

are integrated ideas. Traditional notions of equity have assumed that to achieve equity, Black and Latinx students needed some "special considerations" to address the historical inequities that have plagued these groups. By focusing on the practices of science and engineering through an equity lens, our project team looked for natural intersections of these practices to Latinx and Black students' ways of knowing (Kelley & Knowles, 2016), norms and values, social and cultural experiences, and who they are. Further, this principle is guided by the questions: What does it mean to be a Latinx or Black student who engages in Science and Engineering Practices? What are the ways of doing science and engineering that are "natural" to the way I live my life and solving problems? The answers to these questions drive our work, sending the message that Black and Latinx children do not need to be "special" to engage in STEM nor do they have to disconnect from their communities and values to engage in STEM pursuits. The Science and Engineering Practices and STEM content are inherent in who they are and how they live their lives and are highlighted in all that we do. We thus ensure that this message is received by all young people who engage with *Hero Elementary*, their families and their communities.

Understanding STEM as Literacy

The literature on early literacy and English Language Learning, and the *Ready to Learn* program, all espouse the notion that "school readiness" is essential to school success and that all students should be exposed to early learning and literacy experiences that will prepare them to be successful in formal school contexts (Zollman, 2012). Scholars in these areas have emphasized that literacy, English language proficiency, and overall success in formal education requires a focus on how literacy is embedded in the lives of young learners and supporting them in making the connection between their informal language experiences and more formal ways of expressing themselves. Besides, scholarship in these areas asserts that various forms of media content can be utilized to improve young children's cognitive, social, emotional, literacy and numeracy skills in ways that foster an early interest in learning and ensure that they are "ready to learn."

Recently, a focus on how STEM learning can be used to foster early literacy and English language proficiency has given rise to initiatives such as Science, Technology, Engineering, Arts and Mathematics (STEAM), interdisciplinary education, reading across the curriculum, and whole language integration in STEM curricula and instruction (Zollman, 2012; Pat-

rick, Mantzicopoulos & Samarapungavan, 2009; Mantzicopoulos, Patrick & Samarapungavan, 2013; Mantzicopoulos & Patrick, 2011). This expanded focus on STEM as a way to support young children in being ready to learn has provided an expanded view on the role of STEM as a context for literacy, English Language Learning, and helping all children be prepared for future learning. Hence, the teaching of STEM and the learning of English and literacy (reading, writing, and counting) are not separate endeavors but are innately interconnected.

One of the fundamental principles of this project is to promote the idea that to be an engaged STEM learner not only requires literacy, but is a form of literacy. This notion moves us from the idea that literacy must be "integrated" in STEM experiences to one that espouses that STEM is a form of literacy. To learn STEM is to be literate and Latinx and Black students are inherently doers of STEM; hence they are naturally competent literary agents. We believe that one cannot live life without STEM since life itself is STEM, and all students can naturally express themselves through their own lived realities, STEM can be viewed as a form of literacy that will support young children in being fully literate and ready to learn. We will focus on how young children naturally express themselves, how these expressions relate STEM learning and how they can express their emerging understandings of their world (STEM) in literary avenues such as speaking and writing. For English language learners, this is particularly important because their informal expressions are in another language and this language misalignment has sometimes been viewed as a cognitive issue (Martiniello, 2008; Nora, 2013); at the same time, evidence shows that supporting students' development in both their home language and English actually enhances and supports cognitive development (Martiniello, 2008; National Academies of Sciences, Engineering, and Medicine, 2017). We know that students who are learning English have ways of expression that may not be valued in traditional school settings; hence, this framework acknowledges how these students can and do express their lived experiences and do not view their language difference as a barrier. We aim to support learners in expanding their capacity to express their STEM experiences through enhanced language development.

The message that we wish to send is that STEM is a form of literacy and STEM is fundamental to every student's lived realities. Hence, all students are literate and ready to learn, and we provide ways for them to interpret their social, cultural and personal experiences in ways that reflect STEM understandings. STEM literacy is as natural as their expressions, and we support early learners in translating these expressions in various literary forms.

TRANSFORMATIVE TRANSMEDIA FRAMEWORK FOR EARLY STEM LEARNERS: STRATEGIES FOR INTEGRATION IN MULTIMEDIA CONTEXTS

In this section, we identify strategies for integrating each of the Guiding Principles of the Transformative Transmedia Framework for Early STEM Learners into the transmedia contexts utilized by *Hero Elementary*. We met with various constituencies to further develop and refine these strategies. These constituencies included the developers of digital and analog games, television, hands-on learning activities and digital science notebook pages, outreach, and professional development. In the sections that follow, we not only provide strategies to implement these strategies, but also how multimedia content developers should think about each principle as they are developing content and the overall message that should be sent to early STEM learners.

Addressing the Intersectionality of Racial, Gender, Cultural and STEM Identities for Young Learners and Dispelling Negative Stereotypes: Help young learners connect their racial, cultural and STEM identities and refute negative stereotypes.

Think about: How can we support children in the intersection of their racial, class, cultural, and STEM identities? How do we dispel and refute negative stereotypes?

Message for young learners: We are competent and confident lifelong STEM learners, doers and community members. We contribute to our communities through our STEM learning. It is who we are, and we belong here.

Television	• Emphasize community and sense of belonging and that the characters are a viable part of a STEM community. • Work to find the balance: connect what characters do in STEM with who they are. • STEM is not just for the "special" ones; show all the characters engaged in all aspects of STEM. • Develop backstories and interests in the characters so that these make sense for who they are – what are their interests, hobbies, quirks, etc. • Have characters explore STEM issues that impact their lives, families, and communities. • Involve writers and other production staff whose lived experience resonates with our characters' identities and with our audience. • Characters act as role models/exemplars of the cultural, linguistic, cognitive, social, and emotional assets that diverse students bring to the classroom. ◦ Examples: ▪ Spanish language ▪ High levels of emotional and social development (warmth, physical affection) ▪ Strong family support - familismo (sense of unity and admiration that guides family interactions)
Hands-On Activities and Digital Science Notebook Activities	• Activities that focus on ways children's racial and cultural identities are aligned with being STEM doers and innovators. • Notebook pages encourage children to express their STEM learning in ways that align with their intersectional identities. • Connecting hands-on activities and notebook pages to children's culture and everyday lives.

Games	• Characters and experiences in games reflect children's identities; feature principles that resonate with and engage diverse learners, etc. • Build on characters' backstories from TV – continuing to emphasize that these characteristics make sense for who they are. • When designing games, consider cultural values, "ways of knowing," preferred modes of learning of Latinx and Black kids. • Character customization, students can create characters that reflect themselves. • Use constructivist pedagogical approaches to engage diverse learners. • Involve game developers whose lived experience resonates with our characters' identities and with our audience. • Player agency, that makes sense for players (i.e., who they are) in that situation. • Interactions with other characters in games have to make sense for the player. ◦ For example, Batman as a billionaire can be alienating for children from low-income communities, so highlight characteristics that will resonate better.
Educational Outreach and Family Engagement	• Approach communities from an asset-based perspective, to shape and support positive STEM identities for Black and Brown children. • Support educators to facilitate conversations around STEM, especially with respect to race, culture, class. • Consider cultural values to effectively engage diverse children and their families; for example: ◦ Building relationships and establishing trust. ◦ Integrating experiences that are culturally relevant and meaningful. • Partner with organizations that work effectively with Black and Brown children and families, and that have diverse staff.
Professional Development	• Supporting educators to build positive relationships with Latinx and Black children. • Empower educators to become culturally responsive, effective communicators.

***Grounding "Real World" STEM Experiences in the Lived Realities of Diverse Learners*:** Provide real-world STEM experiences grounded in the lived realities of diverse learners.

Think about: What does it mean to ground STEM experiences in the lived realities of children from diverse communities? How can we do this in *Hero Elementary*?

Message: The real-world experiences that Latinx and Black children have within their reach provide opportunities to learn STEM and to address the needs of their communities.

Television	• Feature realistic environments that feel familiar to Black and Latinx children. • Build stories around real world activities that are grounded in what matters to Latinx and Black children and what's important to their communities. • Music and other sounds should be familiar and comfortable for children from diverse backgrounds. ◦ Vary musical styles and sounds, be as inclusive as possible overall. • Tools and materials should reflect real world experiences of children from diverse backgrounds. • Superpowers of show characters grounded in their realities as Black and Latinx children. • Given that the stories start when the show characters get to school, look for ways to bring in their lived realities – e.g., involve characters' family members.
Hands-On Activities and Digital Science Notebook Pages	• Feature real-world activities grounded in what matters to Black and Brown children. • Consult with diverse children throughout the activity development process. • Notebook activities become places to connect STEM activities with children's lived experiences, ways of knowing, and what's important to their communities.
Games	• Games are grounded in the lived realities of diverse learners by reflecting the environments and spaces of various cultural groups. • Games reflect the big ideas of STEM that connect to children's realities.

Educational Outreach and Family Engagement	• Outreach activities are developed and tested in partnership with community stakeholders. • Talk with families and educators about STEM activities they are already doing. • Work collaboratively to enrich the experiences within lived realities in the community.
Professional Development	• Support educators in understanding STEM as fundamental to the lived experiences and identities of Latinx and Black children.

Recognizing and Integrating Social and Cultural Assets in STEM Powers and Experiences: Integrate social and cultural assets in young learners' STEM powers and experiences.
Think about: Where do we see the cultural assets that communities bring to STEM?

Message: A Black or Brown child, or a child from a low-income family, does not have to be "exceptional" to engage in STEM learning; they are already a part of STEM communities and a historical lineage of success in STEM.

Television	• Focus on STEM powers to support community and social justice outcomes. • Creating something out of "nothing" – games, toys, etc. – resourcefulness, initiative, persistence. • Navigating culture when you don't speak the language. • Strengths of being female in a male-dominated world. • Heroes are not special, they're just representative. • Difference between supers and non-supers, what does it mean to be a hero in power and the non-power world, what's expected from them. • Teamwork, collaboration as core values. • Music, sounds, tools, and materials should reflect real world experiences of children from diverse backgrounds. • The Superpowers of Science (Science and Engineering Practices) are powers that everyone has and that everyone can use. You don't have to be "special" or uniquely talented to use them.

Hands-On Activities and Digital Science Notebook Pages	• Integrate cultural content in hands-on activities. • Place-based learning. • Funds of knowledge.
Games	• Games are co-designed and co-created with communities and are used as mutually beneficial social and cultural resources. ◦ For example, Operation Investigation, an app for family science. • Games are pro-social and build community.
Educational Outreach and Family Engagement	• Outreach programming takes into account asset mapping of the diverse communities in which programming takes place. • Meet with the community to get engagement/involvement before program development. • Invite the community to vet what we're doing. • Do not marginalize folks, our audience gets marginalized in their daily lives so we do not want to perpetuate that. • Ensure that participating organizations are not engaged in a "savior complex" with respect to their communities. • Encourage and cultivate children; their communities are viable and have things to offer for STEM learning. • Have a family kickoff event. • Create a workshop on how to personalize and localize for communities. • Find ways to support community participation; this helps to address power dynamics. • The process of bringing in the community makes the project more viable.
Professional Development	• Support educators to implement Culturally Responsive Teaching (citation here?). • Help educators understand their programs' communities as full of STEM assets, so as to help cultivate what they've got and what children bring to STEM discourse.

Integrating Equity within Science and Engineering Practices: Engage young learners in the Science and Engineering Practices through a comprehensive equity lens.

Think about: In what ways can we see the Science and Engineering Practices as equity practices? How do we make this happen in *Hero Elementary*? What does it mean to be a Latinx or Black student who engages in Science and Engineering Practices? What are the ways of doing science and engineering that are "natural" to the way Black children, Latinx children, and children who live in low-income families, live their lives and the way they go about solving problems?

Message: For Black and Latinx children, the Science and Engineering Practices and STEM content are inherent in who they are and how they live their lives; these will be highlighted in all that we do. Latinx and Black children, as well as children who live in low-income families, come from communities that value STEM and they engage in STEM-related activities in their day to day lives. Hence, the pursuit of STEM is not reserved for children with special skills or talents, it is an endeavor that ALL students can and do engage in every day.

Television	• Utilize the "Superpowers of Science" prominently in TV episodes. These superpowers embody the Science and Engineering Practices from the NGSS ; they are powers that everyone has and everyone can use.
Hands-On Activities and Digital Science Notebook Pages	• Offer culturally relevant approaches to Science and Engineering Practices within hands-on activities. • Opportunities to express Science and Engineering Practices through culturally relevant expressions in the notebook.
Games	• Games provide opportunities for agency and building STEM identity by engaging in the Science and Engineering Practices in culturally appropriate ways.
Educational Outreach and Family Engagement	• Collaborate with communities and families to recognize and reinforce ways that their cultural ways of knowing to intersect with Science and Engineering Practices.
Professional Development	• Support educators to make connections between Culturally Responsive Teaching. and Science and Engineering Practices.

Understanding STEM as Literacy: Help young learners experience STEM as literacy in ways that promote authentic self-expression and language proficiency.

Think about: What does it mean to experience STEM as literacy? How can we help children use STEM to express themselves via *Hero Elementary*?
Message: STEM is a form of literacy and STEM is fundamental to every student's lived realities. Hence, all students are literate and ready to learn, and we provide ways for them to interpret their social, cultural and personal experiences in ways that reflect STEM understandings. STEM literacy is as natural as their expressions, and we support early learners in translating these expressions in various literary forms.

Television	• Feature multiple modes of communication in TV episodes – e.g., visual, verbal, gestures, written. • Use culturally appropriate vocal emphasis and inflection. Hire appropriate voice talent that authentically reflects who the characters are. • Include use of hand gestures when appropriate for emphasis (only with appropriate characters). • Have each child character take on different aspects of action and problem-solving in different situations. • Balance realism and fantastical visual elements to engage diverse learners and support various ways of knowing and expression. • Avoid idiomatic language, to support English Learners. • Science and Engineering Practices (Superpowers of Science) are skills that help children understand ("read") the world around them, communicate their understanding, and use evidence to clarify their thinking.
Hands-On Activities and Digital Science Notebook Pages	• Activities offer multiple ways for children to express themselves (speaking, creating music, writing, creating charts, etc). • Reinforce the idea that Black and Brown children's environments and experiences are grounded in STEM and provide ways for them to express the connection between their realities, STEM ideas, and expression (literacy).

Games	• Games allow for a balance of realism and fantasy that engages diverse learners and allows various ways of knowing and expression to be integrated into gameplay. • Incorporate various languages and dialects. Hire voice talent that authentically reflects the characters.
Educational Outreach and Family Engagement	• Encourage families to use their home languages to communicate about science. • Provide family-facing materials in appropriate languages, using a clear and appropriate writing style.
Professional Development	• Support educators in understanding the power of viewing STEM as literacy.

CONCLUSION

The need to develop a Transformative Transmedia Framework grew out of the needs of the *Hero Elementary* project and an analysis of representation of diverse characters in children's media. As a Ready to Learn project, *Hero Elementary* was conceived to support learning and school readiness for children in grades K-2 in underserved populations. The project brought together a multi-disciplinary team of formal educators, community-focused educators, game developers, media producers, and television producers. As the team surveyed the children's media landscape, a few things became clear. First, representation of diverse characters was lacking. According to the U.S. Census Bureau (2012), people who do not identify as "white" made up approximately 40% of the nation's population. However, only 28% of speaking characters in the media were people of color (IDEA, 2016). Looking at children's media (Dobrow, 2016), we found that the situation was even more unbalanced: 75% of all speaking characters were white and only 17% were people of color. The remaining 8% were various non-human speaking characters, such as characters from outer space or animals. We were aware that representation was only the beginning. In order to develop a television show, digital games and resources, and an educational program that could engage and support diverse audiences, we needed a comprehensive approach: an equity-focused framework for media-based science and literacy learning to engage children in grades K-2. Finding nothing available, we resolved to create one.

In this article, we provided an overview of a Transformative Transmedia Framework for Early STEM Learners that we used to inform all aspects of multimedia content development for *Hero Elementary*. As we move toward content that is focused on how to engage a diverse audience of early learners, it is important that we restructure how we think about this work. Specifically, as we rely more heavily on multimedia to support our work in increasing the numbers of diverse learners who are viable participants in STEM, we must transform our approach to creating transmedia content to include an emphasis on developing positive STEM identities and dispelling negative stereotypes about who can and will participate in STEM, grounding our work on the cultural experiences and assets of Brown and Black early STEM learners, viewing STEM as literacy, and integrating science and engineering practices. Further, transmedia content must reflect the lived realities of Black and Brown students that send positive messages about their natural abilities, talents and cultural funds of knowledge that support their interest and engagement in STEM. In obvious and subtle ways, these messages must reinforce the idea that all children are "STEM people" and that they can see themselves and their communities positively reflected in all aspects of multimedia.

Although these principles are grounded in theory, we have provided strategies that translate these principles into practice, customized for the issues facing each constituency on our multi-disciplinary development team. We developed training for staff and contract developers, to ensure that everyone working on the project had access to information about the transformative approach to developing transmedia content. All Hero Elementary content undergoes rigorous internal review and formative testing in the community. The Transformative Transmedia Framework for Early STEM Learners has enabled the team to engage in important discussions and make decisions from a shared perspective that addresses the concerns of our audience.

As we continue working with this framework and the strategies for practice, we are looking for ways to deepen developers' use of the principles, extend learning, and develop details that enhance our practice. We invite anyone who is charged with creating content that is designed to appeal to early learners to use these strategies intentionally and also be willing to develop their own approaches and strategies while giving up the idea that they will get it right. One of the major goals of this framework is to provide a perspective that will transform what young learners view in the multimedia space, which will help us move beyond shallow approaches to equitable and inclusive programming to programing that has equity and inclusion embedded into its very essence.

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