Connections between STEM Education and Multimodal Literacy Instruction

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Abstract

STEM education and multimodal literacy instruction offer particular benefits to learners beyond the important 21st Century skill advantages outlined by policy advisors, educators, and CEOs. Both multimodal literacy instruction and STEM education give learners opportunities to move from being *consumers* of knowledge and meanings chosen and disseminated through the lens of the power group to being *producers* of knowledge and meanings across cultures and contexts. STEM education and multimodal literacy instruction offer pathways to meet the diverse academic and affective needs of learners, as well as for educational equity and opportunities, particularly for traditionally underserved populations. This study examines the similarities and differences in the formation and implementation of both STEM education and multimodal literacy instruction, including misconceptions about and obstacles to program implementation. Numerous studies demonstrate the effectiveness of and need for integrated STEM education at the elementary level. Preliminary research also indicates an integrated elementary curriculum might be valuable for delivering multimodal literacy instruction. Future research should focus on the effectiveness of integrated teacher preparation coursework in the areas of both STEM education and multimodal literacy instruction. Both STEM education and multimodal literacy instruction are rooted in goals for interdisciplinary practice. It is time to pursue these goals actively and consistently to ensure comprehensive foundational preparation of students in these areas and maintain their interest and engagement through secondary and post-secondary education, as well as into 21st Century careers.

Keywords: STEM education, multimodal literacy instruction, multilingual, multiliteracies, critical thinking, creative problem solving, inquiry-based learning, culturally responsive teaching, multimodal texts, integrated instruction.

The purpose of this article is to encourage the use of integrated models for elementary STEM education and for elementary multimodal literacy instruction, with the goals of promoting critical thinking and creative problem-solving, culturally responsive teaching and culturally relevant pedagogy, and sustained student engagement in the early grades. While we do review literature on STEM education and multimodal literacy as it pertains to both elementary and secondary education, our primary focus is on elementary education. To this end, we discuss the importance of STEM education and multimodal literacy instruction, the similarities and differences in the formation and implementation of both programs, and misconceptions about and challenges to the implementation of each program. In addition, we examine research on integrated STEM education at the elementary level that might serve as a model for teaching integrated multimodal literacy at the elementary level and ways the interdisciplinary goals of both programs might be explored through teacher preparation coursework. Finally, we suggest avenues for future research.

The Importance of STEM Education and Multimodal Literacy Instruction

Critical Thinking and Creative Problem-Solving

In addition to preparing future generations for changing global economies, both multimodal literacy instruction and STEM education give learners opportunities to move from being *consumers* of knowledge and meanings chosen and disseminated through the lens of the power group to being *producers* of knowledge and meanings across cultures and contexts. Moreover, these models provide opportunities to move from traditional didactic classroom spaces to hands-on, project-based learning environments that promote critical thinking and problem-solving skills.

Daugherty et al. (2017) underscore the importance of integrated STEM instruction for developing students' critical problem-solving skills. They point out that students become empowered by making connections between researching and solving STEM problems:

> Inclusion of engineering and technology at the elementary level provides children with the opportunity to be fully engaged and think critically about the problems that society is facing, especially through use of the engineering design process—which is central to the study of technology and engineering (p. 5).

Bybee (2010) also emphasizes the value of STEM education for helping students adapt and solve problems. He writes, "Students can develop 21st Century skills such as adaptability, complex communication, social skills, nonroutine problem solving, self-management/self-development, and systems thinking" (NRC, 2010, p. 31).

Williams (2015) recommends integrating multimodal literacy with inquiry-based learning, in which students work across disciplines to create digital artifacts that address issues of global importance. Whether issues are global, local, or a bit of both, Wiggins (2009), too, makes the case for authentic writing, the kind of writing that leads to that enduring understanding that in writing, audience and purpose dictate form and content. Planning backwards from the goal of a piece of writing, the "so what?" of the task, makes the task meaningful for students and teachers. Multimodal writing tasks that are part of project-based learning--such as those that follow format of the *UbD* (Understanding by Design) GRASPS (Wiggins & McTighe, 2005)--support this idea. For example, second graders may design a multimodal handbook of classroom procedures for when new students join the class, or fifth graders may create a podcast about school family events that can be posted to school social media sites. Wiggins argues, "…the point is to open the mind or heart to a real audience--cause a fuss, achieve a feeling, start some thinking. In other words, what few young writers learn is that there are consequences for succeeding or failing as a real writer" (2009, p. 30).

Culturally Responsive Teaching and Culturally Relevant Pedagogy

Gay (2010) and Ladson-Billings (1994) provide the foundational research for culturally relevant teaching and pedagogy. Gay defines culturally responsive teaching "as using the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant to and effective for them" (p. 31). According to Ladson-Billings culturally relevant pedagogy (CRP) "empowers students intellectually, socially, emotionally, and politically using cultural referents to impart knowledge, skills, and attitudes" (pp. 16-17).

Studies in writing research, second language acquisition, foreign language learning, and reading research have examined the integration of various digital texts with literacy instruction (Tardy, 2005; Nelson, 2006; Selfe et al., 2007; Shin & Cimasko, 2008; Vasudevan et al., 2010). Selfe (2007) found the integration of multimodal communication in the classroom benefits students because:

1. it better prepares learners for their future, literate lives in a digitally mediated world;
2. it better matches learners' literacy practices in out-of-class environments; and consequently,
3. it engages and empowers learners to participate in language and literacy instruction. (p. 487)

Kim and Slapac (2015) assert that integrating multimodal texts and composition to expand the view of literacy in the classroom enables educators to access students' resources for linguistic and cognitive processing. Students are more likely to draw upon their background experiences for classroom learning when they are clearly encouraged to do so. Students recognize the separateness of in-school and out-of-school spaces, and schools do not always make or take time to affirm the different semiotics, modalities, and written/spoken communications of culturally and linguistically diverse learners. Educators must develop a space in which students believe they can share their diverse experiences and perspectives and that these experiences and perspectives are valued. "Such discursive space is essential to achieve the goal of transforming differences and conflicts into rich resources of learning and collaboration" (Gutierrez et al., 1999, p. 21). This "third space" as it is called is where one's home, family, and social network intersects with institutional constructs, such as school, work, or places of worship, for example (Moje et al., 2004). The third space aligns with multimodal literacy instruction, because it "brings competing knowledges and modes of communication into a conversation by challenging and reformulating the current academic literacy practices and discourses in youths' lives" (Kim and Slapac, 2015, p. 21).

With regard to STEM education, Leonard et al. (2018) write, "CRP creates the opportunity for students to learn in a third space where ethnic ways of knowing and core identities are valued alongside dominant canons of knowledge (Brown-Jeffy & Cooper, 2011; Gay, 2010; Lipka et al., 2005)" (p. 387). Culturally responsive STEM education research, with traditionally underserved populations, includes students identifying relationships between STEM applications and engineering students' daily lives (Wilson-Lopez et al., 2016), students producing their own scientific inquiry paths, connecting them to real-world models (Buxton, 2006), and students finding solutions to authentic math problems related to their lives and where they live (Ensign, 2003; Razfar, 2012). "Preparing underrepresented students in the United States with the STEM (science, technology, engineering, and mathematics)/ICT skills needed to fill 21st-century jobs is both a national priority (National Science Foundation [NSF], 2010) and a social justice imperative (Leonard & Martin, 2013)" (Leonard, et al., 2018).

In their study of one integrated STEM educator facilitating an elementary engineering lab, Daugherty et al. (2016) found evidence for integrated STEM education as a means of meeting the diverse academic and affective needs of students. They write:

> Melida* has found that many students who struggled in the traditional classrooms seem to soar in the engineering lab. In the lab, students have an opportunity to learn through the application of knowledge. Melida has also noticed that many students who are considered gifted in traditional classes actually depend upon teammates who struggle in traditional classroom settings. This does so much for the struggling students' self-esteem that it carries over into other areas of their lives. Students have also begun to recognize they have talents they have never explored previously (Daugherty et al., 2016, p. 34).
>
> * From a personal interview

Calls for Multimodal Literacy Instruction and for STEM Education

The New London Group and the New Literacies

In 1994 an interdisciplinary group of international scholars came together to talk about ways to address the growing educational inequity they were observing in traditionally underserved populations with which they worked, specifically regarding changing technological contexts for literacy pedagogy. Since they met in New London, Connecticut, they called themselves "The New London Group" (Cope and Kalantzis, 2009). The group formulated the concept of "multiliteracies," a view of literacy that addresses the intersection of a growing globalized community and rapidly changing technology (New London Group, 1996). Two key aspects of multiliteracies (the two "multis") are multilingual and multimodal (Cope and Kalantzis, 2009). Multilingualism encompasses not only the diversity of languages in the global community, but also "social languages" (Gee, 1990). "Cyberpunks and physicists, factory workers and boardroom executives, policemen and graffiti-writing urban gang members engage in different literacies, use different 'social languages,' and are in different discourses…And, too, the cyberpunk and the physicist might be one and the same person, behaving differently at different times and places" (Gee, 1990, p. 4). Multimodal refers to the linguistic, visual, aural, gestural, and spatial pathways or "modes" through which we understand and create meaning across different media and cultural contexts (Cope and

Kalantzis, 2009). Social semiotic theory (Kress, 2003) provides a framework for knowledge of how we use many different, but frequently intersecting sign systems to make meaning multimodally.

The New London Group (1996) maintained that the changing literacies had implications for "creating access to the evolving language of work, power, and community, and fostering the critical engagement necessary for them to design their social futures and achieve success through fulfilling employment" (p. 60). Cope et al. (2009) discuss ways the new literacy pedagogy supports learners as they develop strategies for navigating the different discourses resulting from increased globalization and fast-changing communication technologies. Jewitt (2008) points out, "The terrain of communication is changing in profound ways and extends to schools and ubiquitous elements of everyday life, even if these changes are occurring to different degrees and at uneven rates" (Luke & Carrington, 2002, p. 241).

Serafini (2013) suggests a three-part pedagogical approach to multimodal literacy instruction consisting of "exposure, exploration, and engagement" (p. 92), as a means of slowly increasing students' literacy experiences with what the author terms, "multimodal ensembles" (p. 91). Serafini draws upon Pearson and Gallagher (1983) stating:

> As teachers journey from the exposure phase, immersing students in a wide variety of texts, through the exploration phase, investigating these texts in greater detail, and eventually the engagement phase where students experiment with producing and disseminating these texts, teachers relinquish their responsibilities for interpreting and creating various multimodal ensembles as students accept more responsibility across these roles (Pearson & Gallagher, 1983) (Serafini, 2013, p. 92).

STEM Education

The acronym STEM for the fields of Science, Technology, Engineering, and Mathematics was first used by the National Science Foundation (NSF) in the 1990s (Sanders, 2009). STEM education concerns learning and instruction in all four of these fields. STEM education programs can be found at all grade levels, as part of the school day and/or in after-school formats (Gonzalez & Kuenzi, 2012). Gonzalez and Kuenzi point out that policy concerns regarding education in these fields date back to George Washington's first State of the Union Address and that today "the economic and social benefits of scientific thinking and STEM education are widely believed to have broad application for workers in both STEM and non-STEM occupations" (p. 1). In 2007 President George W. Bush signed the America COMPETES Act, otherwise known as the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act, which "authorized STEM education programs at the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), Department of Energy (DOE), and Department of Education (ED)" (Gonzalez & Kuenzi, 2012, p. 2). Subsequent administrations have also pushed for funding for STEM education initiatives including President Barack Obama's Let Everyone Dream campaign for youth from traditionally under-represented groups (Fact Sheet, 2015). "As such, many contemporary policymakers consider widespread STEM literacy, as well as specific STEM expertise, to be critical human capital competencies for a 21st century economy" (Gonzalez & Kuenzi, 2012, p. 1).

Challenges to Implementation

When implemented effectively and consistently, STEM education and multimodal literacy instruction offer pathways to educational equity and opportunities, particularly for traditionally underserved populations; nevertheless, each program is beset with challenges to consistent and meaningful implementation. These challenges include common misconceptions surrounding STEM and multimodal literacy instruction and students' lack of interest and engagement with these programs.

The Challenges of Common Misconceptions about STEM Education and Multimodal Literacy Education

STEM vs. STEM Education

Sanders (2009) discusses the importance of making the distinction between STEM and STEM education. "Most, even those in education, say 'STEM' when they should be saying 'STEM education,' overlooking that STEM without education is a reference to the fields in which scientists, engineers, and mathematicians toil. Science, mathematics, and technology *teachers* are STEM *educators* working in STEM *education*. It's an important distinction" (p. 20). The "technology" in STEM is often mistakenly understood to allude solely to computers, and most people—even, or particularly, educators—see STEM education as referring to science or math (Sanders, 2009; Bybee, 2010; Daugherty, 2010), and often as a means "to address perceived problems by heaping on increased expectations and requirements for mathematics and science education" (Daugherty, 2010, p. 19). As Bybee (2010) states, "Once again, the education community has embraced a slogan without really taking the time to clarify what the term might mean when applied beyond a general label" (p. 30).

Education Technology vs. Technology Education

A misunderstanding held by numerous teacher educators, preservice teachers, and in-service teachers is that the terms *technology education* and *education technology* can be used interchangeably. Daugherty (2010) writes:

> First, many assume that the technology in STEM is referring to the implementation of computers and/or instructional technology devices and software. While computers are certainly a part of the equation in technology education, this definition is far too narrow an understanding and represents only one technological tool among many (p. 20).

The definition of education technology has been reassessed and reconfigured over the last several decades (Kurt, 2016). The most recent update to the definition was in 2007 by the

Association for Educational Communications and Technology (AECT): "Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources."

Just as it is for any field of instruction, teacher knowledge of educational technology can be a very important component in making STEM content and multimodal literacy instruction accessible to students; however, using technology as a pedagogical strategy is not the same as the actual teaching of technology or *technology education*. The goal of technology education is to develop students' technological literacy (Daugherty, 2010).

Multimodal Texts: Categories and Examples

Misconceptions about exactly what multimodal texts are can lead to poor literacy instruction. A text is considered multimodal when its meaning is conveyed across two or more modes, which include not only spoken and written language, but also visual, audio, gestural, tactile, and spatial (State of Victoria, 2018). As is the case with the term *technology* in STEM education frequently being used synonymously with *computers* and related *devices*, an assumption often made in multimodal literacy instruction is that multimodal texts are synonymous with digital texts. While there are numerous examples of digital multimodal texts such as film, social media platforms, blogs, animation, and so on, many multimodal texts are not digital in nature. Picture books, graphic novels, and posters are all examples of multimodal texts that may or may not be digital. In addition, live performances such as theater, dance, concerts, and storytelling are also multimodal texts that convey meaning:

> Each mode uses unique semiotic resources to create meaning (Kress, 2010). In a visual text, for example, representation of people, objects, and places can be conveyed using choices of visual semiotic resources such as shape, size, line, and symbols, while written language would convey this meaning through sentences using noun groups and adjectives (Callow, 2013), which are written or typed on paper or a screen (State of Victoria, 2018, para. 5).

Multimodal literacy is about making meaning from texts and conveying meaning through composition. Literacy teachers who feel these areas are sufficiently covered by students reading online articles and writing papers using Google docs are mistaken. As Truman Capote is reported to have said about the work of Jack Kerouac and other Beat poets, "That's not writing. That's typing."

The Challenges of Student Engagement

Research shows that fewer and fewer students are choosing to take STEM classes in high school, and those who do are not necessarily continuing to pursue these fields in college and careers (Daugherty et al., 2017; Sawchuk, 2018). Despite policy initiatives and designated funding for STEM education, studies show graduates from high schools offering substantial numbers of STEM classes are no more likely to major in STEM fields in college than are graduates from secondary schools with fewer STEM course offerings (Sawchuk, 2018). Daugherty et al. (2017) write that “alarming numbers of students seem to be opting out of STEM programs of study at the secondary and postsecondary levels, many making the decision to avoid STEM courses and programs of study as early as fourth or fifth grade” (p. 12).

Interestingly, assumptions about students being naturally drawn to multimodal literacy classroom practices are also often wrong (Braziller & Kleinfeld, 2015; Stowe, 2012; University of Michigan, n.d.). Teachers may think that because students engage daily with multimodal texts through social media, text messaging, news apps, video apps, and so on, they will actively engage in and even prefer multimodal text analysis and composition. In fact, students are generally used to accessing these texts in an uncritical way and will need clear instruction and modeling in order to analyze and make meaning from multimodal texts, just as they must be taught to close read or analyze alphabetic texts (University of Michigan, n.d.). Regarding multimodal composition, particularly with secondary and post-secondary students, Braziller and Kleinfeild (2015) write:

> They have grown up watching YouTube, listening to sound bites, doing all of their communication on a phone. But this doesn’t mean that they have done a lot of composing. Sometimes they initially resist the idea of creating multimodal compositions, preferring the familiar, the text, the essay. They believe that’s easier because they are already familiar with it. The reality is that you will have to sell your students on the value of a composition class whether you take a multimodal approach or a traditional approach (para. 6).

Obstacles to consistent, engaging implementation of STEM education and multimodal literacy instruction (common misconceptions surrounding STEM and multimodal literacy instruction, and students’ lack of interest and engagement with these programs) may be more effectively addressed through integrated instruction beginning in elementary grades. STEM education programs have been commonly implemented at secondary and post-secondary levels. The same is generally true for multimodal literacy instruction. Emphasis on high-stakes testing encourages silo approaches to content-area instruction in upper grades. This results in missed opportunities for interdisciplinary, integrated practices that promote learning motivation and transfer of knowledge (Wiggins and McTighe, 2005).

Integrated Instruction at the Elementary Level

Satchwell and Loepp (2002) explain that “an integrated curriculum is one with an explicit assimilation of concepts from more than one discipline. As much as possible, integrated curricula apply equal attention to two or more disciplines (Huntley, 1999)” (para. 3). Kress (2010) describes multimodal literacy as “a framework that requires a collective interpretation of two or more scripts, visuals, videos, graphics, animations, sounds, music, gestures, and facial expressions for producing meaning” (p. 54). Research suggests that beginning integrated STEM education programs and multimodal literacy instruction gives teachers a chance to support young learners’ inherent curiosity about the world around them.

Murphy (2011) writes, “Children at birth are natural scientists, engineers, and problem-solvers. They consider the world around them and try to make sense of it the best way they know how: touching, tasting, building, dismantling, creating, discovering, and exploring. For kids, this isn’t education. It’s fun!” (Murphy, 2011, para. 5 as cited in Daugherty et al., 2017). Likewise, Cope et al. (2018) maintain young children possess innate multimodal dispositions:

> Let’s consider that when a child is born, they look, they touch, they feel. They are multimodal; that’s how they make meaning. And what do we do to them? We put them in school and as they go through the grades, we strip all that out. We say read, write, read, write, test, read, don’t touch, don’t move, don’t scribble. The essay or the tick-a-box test for correct usage become the way of expressing knowledge (para. 8).

There are widespread calls for STEM education. There are policy initiatives and funding for STEM education. In response, many school districts have chosen to begin STEM coursework in secondary grades. Schools that teach STEM fields in elementary grades generally focus on math and science, particularly math, since this content area is subject to elementary standardized testing. Engineering is usually de-emphasized in the curriculum and technology taught in a peripheral manner. Nadelson et al. (2013) point out that elementary education builds the foundation for and interest in the STEM fields, yet elementary teachers’ lack of training and sense of efficacy may impact student engagement and learning in science, technology, engineering, and math. This, in turn, can have implications for whether students go on to pursue further studies and careers in these fields. Carr et al. (2012) note that 41 states have engineering-related curriculum standards, many of which are designated for elementary grades, and of course, Next Generation Science Standards (NGSS) recommend developing students’ engineering skills at the elementary level (Next Generation Science Standards (NGSS) Lead States, 2013). Sanders (2009) states:

> Integrative STEM education is not intended as a new stand-alone subject area in the schools accompanied by new “integrative STEM education” licensure regulations, as some might suspect. Given the amount of content knowledge necessary to be an effective science, mathematics, or technology educator, it’s very difficult to imagine a new teaching/licensure program that would prepare individual pre- and/or in-service teachers with sufficient science, mathematics, and technology content expertise—and the pedagogical content knowledge—to teach all three bodies of knowledge effectively (p. 21).

Daugherty et al. (2017) assert that effective teacher preparation in elementary STEM education must not only emphasize standards in science, technology, engineering, and math, but also develop teacher enthusiasm for helping students make interdisciplinary connections.

Calls for multimodal literacy instruction are not nearly as widespread as those for STEM education, and they have largely been ignored. Schools continue to emphasize print literacy because that aligns with high-stakes testing. In teacher education programs, as well as in elementary classrooms, teaching with and about multimodal texts is often viewed as a strategy for scaffolding students until they are ready for "real" texts. Again, the often-peripheral use of technology by teacher educators and classroom teachers reflects views that multimodal composition is addressed by having students compose print texts with a keyboard, occasionally inserting pictures found on the internet, and creating presentations for class projects, usually PowerPoints or Prezis. In addition, more and more state departments of education are requiring the Foundations of Literacy test as part of teacher licensure. This will no doubt result in even less emphasis on multimodal literacy in elementary literacy methods coursework. This is short-sighted, of course, for without the ability to access, navigate, and comprehend multimodal texts, students will not have the skills for critical media literacy, real-world communication, and workplace applications.

"One of the biggest challenges when adding anything to the elementary curriculum is finding a proper context in which to enact it. Many teachers do not have much experience with multimodal literacy concepts (which is a challenge in its own right) and are accordingly unsure of where these concepts may be introduced in the curriculum" (Serafini, 2015, p. 419). Williams (2015) asserts that avoidance of technology instruction by teachers may be reinforced (albeit unwittingly) by teacher preparation programs. Preservice teachers often enter teacher education programs with firmly held views of literacy as a "print-bound process" (para. 3), and technology education courses are usually offered as separate courses from literacy methods classes. She writes, "Though these courses are designed to show construction of knowledge in the area of technology integration, they are often presented in isolation, unable to demonstrate the importance of incorporation of practice across the curriculum and throughout content areas" (para. 3). As Cope et al. (2018) state:

> This has huge pedagogical implications, not just about what we might do, but what we probably have to do. Learners come to school with a different set of sensibilities. The phrase that Mary and I used to describe that is a shift in the "balance of agency" (Cope & Kalantzis, 2009, p. 172). But here's the contradiction: What do we see in schools? Let's take the flipped classroom. It's using new multimodal technologies for yet another transmission from one to many. So, in some sense it's not a change at all, because a real change would be to have the kids research the topic and make the video themselves or write the text themselves (p. 9).

In a study on how prepared educators are to teach multimodal composition, Chandler (2016) writes this regarding his findings: "If the participants claim to have any relevant background at all, they tend to be self-taught or perhaps having attended a brief in-service program. Mid-career teachers seem to be the least engaged in any structured learning" (p. 14).

Future Research

"Advocates of more integrated approaches to K–12 STEM education argue that teaching STEM in a more connected manner, especially in the context of real-world issues, can make the STEM subjects more relevant to students and teachers" (Honey et al., 2014). While there is still much work to be done to address the urgent issues in STEM education, STEM educators, particularly those in teacher preparation programs are developing ways to address these issues.

Recommendations for integrated STEM in the elementary grades, outreach programs in which STEM teacher educators work with classroom teachers to deliver integrated STEM content, scholarships, and other funding to encourage students to pursue STEM fields are some of the purposeful solutions to problems in STEM education. Many elementary teacher preparation programs require STEM methods coursework, but for many programs, STEM coursework is still elective in nature. Effective STEM methods coursework provides teacher candidates with a foundation for teaching engineering design. "But curricula that emphasize the performative dimension of engineering are particularly suited for students traditionally experiencing difficulties in STEM subjects—including those marked learning disabled—because it supports literacy in a manner that transcends modes" (Roth, 2017, p. 261). Coursework in STEM education may greatly augment the preparation of future K-6 teachers. Leaders in teacher education may wish to also consider delivering elementary methods coursework in the STEM fields in an integrative manner as a tool for replicating practices in the primary school. This would enable preservice teachers to participate in and see the integrative model in action at the post-secondary level. Of course, this would also require a great deal of cooperation on the part of faculty members who teach methods courses in elementary math, science, technology, and engineering, but this interdisciplinary collaboration would be particularly useful for future fifth- and sixth-grade teachers who are often departmentalized in elementary schools and are almost always departmentalized in middle schools.

"Multimodal literacies instruction . . . enables children to have creative autonomy, to think and act in unique ways, and allows all children to have academic access through dynamic paths" (Sanders, 2010, p. 131). Teacher educators in literacy instruction may have a worthy model from the field of STEM education, where leaders have called for integrated instruction at the elementary level. Like many teacher education programs in STEM, literacy teacher educators might consider developing programs to provide training for and work with classroom teachers to build their confidence in teaching elementary multimodal literacy instruction--instruction that neither excludes nor privileges traditional print texts. Just as elementary teacher educators in STEM fields are encouraged to consider delivering teaching methods coursework in an integrative manner, elementary literacy teacher educators might benefit from an intra-disciplinary methods coursework delivery system. To ensure fully integrated, comprehensive, multimodal literacy education for preservice teachers, teacher educators in literacy could also plan instruction through interdisciplinary approaches with faculty in elementary content-area methods courses.

Both STEM education and multimodal literacy instruction are rooted in goals for interdisciplinary practice. This may well be the perfect opportunity to pursue these goals actively and consistently to ensure comprehensive, foundational preparation of students in these areas, and to maintain their interest and engagement through secondary and post-secondary education, as well as into 21st Century careers.

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References

Association for Educational Communications and Technology (2007). Definition. A. Januszewski, & M. Molenda (Eds.), Educational technology: A definition with Commentary (pp. 1 – 14). New York: Lawrence Erlbaum Associate.

Albers, P. (2006). Imagining the possibilities in multimodal curriculum design. *English in Education*, *38*(2), 75-101.

Braziller, A., & Kleinfeld, E. (2015, September 3). Myths of multimodal composing. [blog post]. Retrieved from http://www.digitalrhetoriccollaborative.org/2015/09/03/myths-of-multimodal-composing/

Buxton, C. A. (2006). Creating contextually authentic science in a "low-performing" urban elementary school. *Journal of Research in Science Teaching, 43*, 695–721.

Bybee, R. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, *70*(1), 30–35.

Carr , R., Bennett , L., & Strobel, J. (2012). Engineering in the K–12 STEM standards of the 50 U.S. States: An analysis of presence and extent. *Journal of Engineering Education*, *101*(3), 539 – 564.

Chandler, P. (2013). Middle years students' experience with new media. *Australian Journal of Education, 57(3)*, 256–269.

Chandler, P. (2017). To what extent are teachers well prepared to teach multimodal authoring? *Cogent Education*, *4*, 1-19.

Cope, B., & Kalantzis, M. (2009). "Multiliteracies": New literacies, new learning. *Pedagogies: An International Journal*, *4*(3), 164-195.

Cope, B., Kalantzis, M., & Smith, A. (2018). Pedagogies and literacies, disentangling the historical threads: An interview with Bill Cope and Mary Kalantzis. *Theory into Practice*, *57*(1), 5-11.

Dare, E., Ellis, J., & Roehrig, G. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study. *International Journal of STEM Education*, *5*(4), 1-19.

Daugherty, M. K. (2010). The 'T' and 'E' in STEM. In ITEEA (Ed.), *The Overlooked STEM Imperatives: Technology and Engineering* (pp. 18-25). Reston, VA: ITEEA.

Daugherty, M., & Carter, V. (2018). The nature of interdisciplinary STEM education. In M. de Vries (Eds.), *Handbook of Technology Education* (pp. 159-171). New York: Springer International Publishing.

Daugherty, M., Carter, V., & Havice, W. (2016). Elementary education: Teaching in an integrated STEM program. In M. Hoepfl (Ed.), *Exemplary Teaching Practices in Technology & Engineering Education* (pp. 33-54). Reston, VA: Council on Technology and Engineering Teacher Education (CTETE).

Daugherty, M., Kindall, H., Carter, V., Swagerty, L., & Wissehr, C. (2017). Integrating informational text and STEM: An innovative and necessary curricular approach. *Journal of STEM Teacher Education*, *52*(1), 3-15.

Eksi, G., & Yakisik, B. Y. (2015). An Investigation of Prospective English Language Teachers' Multimodal Literacy. Procedia - Social and Behavioral Sciences, 199, 464-471.Ensign, J. (2003). Including culturally relevant math in an urban school. *Educational Studies, 34,* 414-423.

Fact sheet: President Obama announces over $240 Million in new STEM commitments at the 2015 White House Science Fair. (2015, March 23). Retrieved from https://obamawhitehouse.archives.gov/the-press-office/2015/03/23/fact-sheet-president-obama-announces-over-240-million-new-stem-commitmen

Gay, G. (2010). *Culturally responsive teaching: Theory, research, and practice* (2nd ed.). New York, NY: Teachers College Press.

Gee, J. (1990). *Social linguistics and literacies*. London: Routledge.

Gonzalez, H., & Kuenzi, J. (2012). *Science, technology, engineering, and mathematics (STEM) education: A primer*. Washington, DC: Congressional Research Service.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington, DC: National Academies Press.

Hsu, Y., Hung, J., & Ching, Y. (2013). Hsu, Y. Trends of educational technology research: more than a decade of international research in six SSCI-indexed refereed journals. *Educational Technology Research and Development, 61*(4), 685–705.

Jewitt, C. (2008). Multimodality and literacy in school classrooms. *Review of Research in Education*, *32*(1), 241-267.

Kalantzis, M., & Cope B. (2016, February 16). Introduction to the concept of literacies [Video file]. Retrieved from https://www.youtube.com/watch?v=OBspDrMPqEo

Kim, S., & Slapac, A. (2015). Culturally responsive, transformative pedagogy in the transnational era: Critical perspectives. *Educational Studies*, *51*(1), 17-27.

Kress, G. (2003). *Literacy in the new media age.* New York, NY: Routledge.

Kress, G (2010). *Multimodality: A Social Semiotic Approach to Contemporary Communication.* London and New York: Routledge, Taylor, and Francis Group.

Kurt, S. (2016, October 12). Definitions of educational technology, in *Educational Technology*. Retrieved from https://educationaltechnology.net/definitions-educational-technology/

Laboy-Rush, D. (2007). Integrated STEM education through project-based learning. *Learning.com*. Retrieved from http://www.rondout.k12.ny.us/common/pages/DisplayFile.aspx?itemId=16466975

Ladson-Billings, G. (1994). *The dreamkeepers: Successful teachers of African American children*. San Francisco, CA: Jossey-Bass.

Leonard, J., Mitchell, M., Barnes-Johnson, J., Unerti, A., Outka-Hill, J., Robinson, R., & Hester-Croff, C. (2018). Preparing teachers to engage rural students in computational thinking through robotics, game design, and culturally responsive teaching. *Journal of Teacher Education*, *69*(4), 386-407.

Luke, A., & Carrington, V. (2002). Globalisation, literacy curriculum practice. In R. Fisher, M. Lewis, & G. Brooks (Eds.) *Raising Standards in Literacy* (pp. 231-250). London: Routledge.

Mervis, J. (2018, December 3). Trump emphasizes workforce training in new vision for STEM education. *Science*, Retrieved from http://www.sciencemag.org/news/2018/12/trump-emphasizes-workforce-training-new-vision-stem-education

Moje, E., Ciechanowski, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly*, *39*, 38–70.

Murphy, T. (2011, August 29). STEM education—It's elementary. *U.S. News & World Report*. Retrieved from https://www.usnews.com/news/articles/2011/08/29/stem-education--its-elementary

Nadelson, L., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers. *Journal of Educational Research*, *106*(2), 157-158.

National Academy of Engineering. *(2008). Changing the conversation: Messages for improving public understanding of engineering.* Washington, DC: National Academies Press.

National Research Council. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington, DC: National Academies Press.

National Science Foundation. (2012). *NSF at a glance*. Washington, DC. Retrieved from http://www.nsf.gov

Nelson, M. (2006). Mode, meaning and synaesthesia in multimedia L2 writing. *Language Learning and Technology*, *10*(2), 56–76.

Next Generation Science Standards Lead States (2013). *Next generation science standards: For states, by states*. Washington, DC: National Academies Press.

Park, H., & Selfe, C. (2011). Student experiences in a multimodal composition class. *English Language & Literature Teaching, 17*, 229-250.

Pearson, P. D., & Gallagher, M. C. (1983). The instruction of reading comprehension. *Contemporary Educational Psychology*, *8*, 317– 344.

Razfar, A. (2012). Vamos a jugar counters! Learning mathematics through funds of knowledge, play, and the third space. *Bilingual Research Journal, 35,* 53-75.

Roth, W. (2017) The thinking body in/of multimodal engineering literacy. *Theory Into Practice*, *56*(4), 255-262.

Ryu, J., & Boggs, G. (2016). Teachers' perceptions about teaching multimodal composition: The case study of Korean English teachers at secondary schools. *English Language Teaching*, *9*(6), 52-60.

Sanders, J. (2010). Relationships between artistic expression and written composing: A qualitative study of fourth-grade students' composing experiences. In P. Albers & J. Sanders (Eds), *Literacies, the arts & multimodality* (pp. 110 - 135). Urbana, IL: National Council of Teachers of English.

Sanders, J., & Albers, P. (2010). Multimodal literacies: An introduction. In P. Albers & J. Sanders (Eds.), *Literacies, the arts & multimodality* (pp. 1-25). Urbana, IL: National Council of Teachers of English.

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher*, *68*(4), 20-26.

Satchwell, R., & Loepp, F. (2002). Designing and implementing an integrated mathematics, science, and technology curriculum for the middle school. *Journal of Industrial Teacher Education*, *39*(3), 41-66. Retrieved from https://scholar.lib.vt.edu/ejournals/JLTE/v39n3/satchwell.html

Sawchuk, S. (2018, March 2). High schools are adding more STEM classes. It may not be enough. *Education Week*. Retrieved from https://blogs.edweek.org/edweek/curriculum/2018/03/common_strategy_to_boost_STEM_enrollment_may_not_be_enough.html

Seels, B. B., & Richey, R. C. (1994). *Instructional technology: The definition and domains of the field.* Washington, DC: Association for Educational Communications and Technology.

Selfe, C. (2007). *Multimodal composition*. Cresskill, NJ: Hampton Press.

Selfe, C., Fleischer, S., & Wright, S. (2007). Words, audio and video: Composing and the processes of production. In C. L. Selfe (Ed.), *Multimodal Composition* (pp. 13–28). Cresskill, NJ: Hampton Press.

Serafini, F. (2013). *Reading the visual: An introduction to teaching multimodal literacy*, Teachers College Press. *ProQuest Ebook Central*, http://ebookcentral.proquest.com/lib/uark-ebooks/detail.action?docID=3544848. Created from uark-ebooks on 2021-09-21 23:11:25.

Serafini, F. (2015). Multimodal literacy: From theories to practices. *Language Arts*, *92*(6), 412-422).

Shin, D., & Cimasko, T. (2008). Multimodal composition in a college ESL class: New tools, traditional norms. *Computers and Composition*, 25(4), 376–395.

State Government of Victoria, Australia. (2018). Multimodal texts. *Multimodal Literacy*. Retrieved from https://www.education.vic.gov.au/school/teachers/teachingresources/discipline/english/literacy/readingviewing/Pages/litfocusmultimodal.aspx

Stowe, S. (2012). Student perceptions and use of multimodal and traditional forms of composition. *All Theses*. 1396. https://tigerprints.clemson.edu/all_theses/1396

Tardy, C. (2005). Expressions of disciplinarity and individuality in a multimodal genre. *Computers and Composition, 22*(3), 319-336.

University of Michigan Sweetland Center for Writing. (n.d.). Supporting multimodal literacy. Retrieved from https://lsa.umich.edu/sweetland/instructors/teaching-resources/supporting-multimodal-literacy.html

Vasudevan, L., Schultz, K., & Bateman, J. (2010). Rethinking composing in a digital age: Authoring literate identities through multimodal storytelling. *Written Communication*, *27*(4), 442–468.

Walsh, M. (2010). Multimodal literacy: What does it mean for classroom practice? *Australian Journal of Language and Literacy*, *33*(3), 211-239.

Wiggins, G. (2009). Real-world writing: Making purpose and audience matter. *The English Journal*, *98*(5), 29-37.

Wiggins, G., & McTighe. (2005). *Understanding by design (2nd ed.)*. Alexandria, VA: ASCD.

Williams, J. (2015, July 22). Five shifts of practice: Multimodal literacies in instruction. *Literacy Daily*. Retrieved from https://www.literacyworldwide.org/blog/literacy-daily/2015/07/22/five-shifts-of-practice-multimodal-literacies-in-instruction

Wilson-Lopez, A., & Gregory, S. (2015). Integrating literacy and engineering instruction for young learners. *The Reading Teacher*, *69*(1), 25-33.

Wilson-Lopez, A., Mejia, J., Hasbun, I., & Kasun, G. (2016). Latina/o adolescents' funds of knowledge related to engineering. *Journal of Engineering Education*, *105*(2), 278-311.

Witte, S. (2007). "That's online writing, not boring school writing": Writing with blogs and the talkback project. *Journal of Adolescent & Adult Literacy, 51*, 92- 96. http://dx.doi.org/10.1598/JAAL.51.2.1