



STEM Equity in Informal Learning Settings: The Role of Public Libraries



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Table of Contents

Executive Summary	4
Introduction	7
Equity, Access, and the STEM Pipeline	12
The Informal Education Landscape	19
Public Libraries—A Promising Direction for STEM Equity and Access	34
Recommendations for Public Libraries	49
Next Steps and Future Directions	52
Conclusions	54
References	55

Glossary of Terms

Access—The ability to utilize or ease of usability, particularly in regard to utilization of STEM educational opportunities.

Active Learning—Learning that engages students in activity (e.g., discussion, writing, creating), rather than passive learning formats where activity is not included in the learning process (e.g., lectures).

Afterschool Program—Programming for students that takes place outside of school time, including before school, after school, during the summer, and on non-school days.

Digital Media—Technologies (e.g., computers, digital music production, video games) that allow users to create new forms of interaction, expression, communication, and entertainment in a digital format (Sebring et al., 2007).

Equity—Equal learning opportunities, particularly in reference to STEM education and learning.

Formal Education—Learning that occurs within schools and school systems, including school libraries.

Free-Choice Settings—Environments in which attendees select how they interact with displays or exhibits and what they learn based on their interests and receive little or no facilitation by institutional members (Bell, Lewensten, Shouse, & Feder, 2009).

Informal Education—Learning that occurs outside of formal education environments, where learning is the intended outcome.

Informal Learning—Learning that occurs outside of formal education environments, where learning is not necessarily an intended outcome.

Inquiry-Based Education—Learning that incorporates educational content with student engagement and responsibility for learning content, as well as student motivation or active thinking (Minner, Levey, & Century, 2009).

K-12—Elementary, middle, and high school, including kindergarten through 12th grade.

Public Library—A library that is open to the community and not governed by any school systems (e.g., K-12 schools, universities).

SES—Socioeconomic status, or level of income of youth and their families.

Science-Rich Institution—Centers of informal education that promote science and/or cultural learning for all people, including museums, aquariums, zoos, nature centers, botanical gardens, planetariums, and other science-based establishments.

STEM—An acronym for the academic subjects of science, technology, engineering, and mathematics. Similar acronyms that are also mentioned in concert with STEM are STEAM (i.e., science, technology, engineering, art, mathematics), STEM-C (i.e., science, technology, engineering, mathematics, computer science), and STE-M (i.e., science, technology, engineering, medicine).

STEM Ecosystem—A learning ecosystem that includes a variety of youth settings such as schools, community centers (e.g., after-school programs, summer programs), science centers and museums, and other types of informal experiences that occur at home and other learning environments. The STEM ecosystem utilizes the unique contributions of each of these youth environments to deliver a rich array of STEM learning opportunities that engage youth and help them become more knowledgeable and skilled in STEM (Traphagen & Traill, 2014).

STEM Pipeline—For STEM fields, the pipeline analogy represents the progression of students engaged in STEM who, through formal educational systems, become qualified to fill the employment positions available. As the United States is experiencing a shortage of qualified workers able to fill STEM positions, the pipeline analogy serves as a tool to discuss the need for educational support for students in STEM.

Executive Summary

Introduction

Science, technology, engineering, and mathematics (STEM) education and programming has become a priority in our nation. In the United States, the STEM pipeline is considered "leaky" as many students disengage from STEM at various points during their lives. In particular, women, Latinos, and African Americans are more likely to disengage from the STEM pipeline. American students are less likely to earn STEM postsecondary and graduate degrees compared to other nations. As careers in STEM fields are expected to increase at a faster rate than other occupations, there is growing concern about the competitive advantage of the U.S. in the global market.

The purpose of this report is to examine how informal education and programming, specifically through public libraries, can provide a viable solution toward increasing STEM equity and access for historically underrepresented K-12 students. This report is divided into seven sections:

- 1) Introduction;
- 2) Equity, access, and the STEM pipeline;
- 3) The informal education landscape;
- 4) Public libraries—a promising direction for STEM equity and access;
- 5) Recommendations for public libraries;
- 6) Next steps and future directions; and
- 7) Conclusions.

Equity, Access, and the STEM Pipeline

Historically underrepresented groups such as girls, ethnic minorities, students from low-income households, and students with disabilities are more likely to disengage from the STEM pipeline. These students face a number of challenges and obstacles because of their social identities such as gender, race, and class. This educational inequality influences how such students engage in STEM both in formal and informal education settings. As a result, these students are less likely to pursue STEM careers and join the STEM workforce. Formal education is not enough to address the leaky STEM pipeline. This section examines equity, access, and the STEM pipeline through the lens of Social Identity Theory.

The Informal Education Landscape

As the United States is facing a scarcity of qualified STEM professionals, informal education may be an avenue through which students can further engage in STEM education to supplement learning in schools and progress in the STEM pipeline. Informal education is described as an

environment that promotes and facilitates STEM education and programming outside of formal education. Informal education occurs across a variety of settings (e.g., informal education institutions, technology platforms) and at differing levels (e.g., afterschool programs, field trips, summer camps). This report focuses on informal education that takes place in unstructured informal education institutions (e.g., museums, zoos, aquariums) and within structured or semi-structured programs (e.g., afterschool programs, out of school). The Afterschool Alliance (2013) recommends the following three developmental outcomes for youth engaged in informal STEM education:

1. Interest in STEM and STEM learning activities;
2. Capacity to productively engage in STEM learning activities; and
3. Value placed on the goals of STEM and STEM learning activities.

These three outcomes—interest, capacity, and value in and for STEM are recognized as the overarching goals of informal STEM education in this report. This section also describes best and promising practices for informal STEM education and programming.

Public Libraries—A Promising Direction for STEM Equity and Access

Over the last few years, there has been a movement toward offering STEM education and programming in public libraries. As a long-standing location for informal education, public libraries are beginning to utilize their existing resources (e.g., Internet access, computers, knowledgeable and friendly staff) as a foundation upon which to expand STEM education. Children and young adults visit public libraries because these institutions provide them a place to access technology (e.g., computers), media (e.g., books, magazines), resources for homework, and provides them a place to socialize with their friends through community events. Public libraries hold great promise for promoting the STEM equity and access of K-12 students. This section also describes best and promising practices for informal STEM education and programming in public libraries to date.

Recommendations for Public Libraries

Based on a thorough review of the literature, the following eight recommendations are offered in this report:

1. Collaborate with STEM stakeholders;
2. Form partnerships with organizations that serve youth;
3. Target historically underrepresented K-12 youth;
4. Make STEM programs accessible and equitable to all youth;
5. Develop strong, lasting, caring adult-youth relationships;

6. Provide training and professional development opportunities to librarians;
7. Evaluate STEM programs and monitor and track outcomes; and
8. Share results with stakeholders.

Next Steps and Future Directions

Engaging students in the STEM pipeline and maintaining their interest in this area is still a relatively new area, particularly for public libraries. As such, there is a dearth of research surrounding the optimal timing to engage and maintain students in the STEM pipeline. Also, understanding the factors that support and hinder K-12 students' interest, engagement, and aspirations in STEM requires further research. For public libraries, evaluating the effectiveness of STEM activities, services, and programs is clearly needed moving forward. Rural students and rural public libraries denote a new direction in this area of research.

Conclusions

In conclusion, public libraries offer a viable solution to address the STEM equity and access issues in our nation. These institutions can provide places, platforms, and programs to support historically underrepresented K-12 students' engagement and persistence in the STEM pipeline. This report is intended for librarians seeking to adopt and strengthen STEM education and programming in public libraries. This report also focuses on current trends and practices in public libraries, especially in the context of STEM education and programming, providing a baseline for what these informal education institutions are currently doing to address this education disparity. The recommendations and resources included in this report provide policymakers, practitioners, researchers, and librarians with tools to implement best and promising practices in this area. Finally, this report discusses areas for future research in the context of STEM education and programming in public libraries. While more research is needed to determine which activities, programs, and services are best for historically underrepresented K-12 populations, it is clear that public libraries hold great promise for the future.

Introduction

Science, technology, engineering, and mathematics (STEM) education and programming has become a priority in our nation. Despite the nation's reputation for being a leader in scientific innovation (Kuenzi, 2008), American high school students ranked 31st for math literacy and 23rd for science literacy when compared to other countries (American Library Association, 2013). American students are also less likely to earn postsecondary and graduate STEM degrees. Chen and Soldner (2013) found that between 2003 and 2009, 48% to 69% of college students in STEM majors had left STEM fields by the 2009 spring semester. Further supporting this trend, the National Science Foundation (2011) found that in 2006, percentages of postsecondary degrees in STEM fields had stayed the same or declined since previous years.

As careers in STEM fields are expected to increase at a faster rate than other occupations (National Science Board, 2010), there is a growing concern about the competitive advantage of the U.S. in the global market (Aschbacher, Li, & Roth, 2010; National Research Council, 2011). Compared to Asia (20%) and Europe (13%), the U.S. produced far fewer college graduates (4%) who majored in engineering in 2003 (Dugger, 2011). Similar trends were observed at the graduate level; 84% of doctoral degrees in STEM were earned by U.S. citizens in 1966, a number which declined to 59% in 2004 (American Library Association, 2013). This trend occurs at the same time that the retirement of the baby boomer generation is expected to produce more than 3 million new STEM positions (Lacey & Wright, 2009), making research into STEM careers and education a national priority.

This report reviews the literature on STEM education and programming, focusing on equity and access consideration of historically underrepresented students, the role of best and promising informal education practices, the public library as an informal education institution that is well-positioned to offer STEM education and programming, and concludes with recommendations for public libraries seeking to offer STEM education and programming. The purpose of this report is to examine how informal education and programming, specifically through public libraries can provide a viable solution toward increasing STEM equity and access for historically underrepresented K-12 students. This report is divided into seven sections: 1) Introduction, 2) Equity, Access, and the STEM Pipeline, 3) The Informal Education Landscape, 4) Public Libraries – A Promising Direction for STEM Equity and Access, 5) Recommendations for Public Libraries, 6) Next Steps and Future Directions, and 7) Conclusions. Each section provides an extensive review of the literature.

The STEM Pipeline

The STEM pipeline provides a framework through which to understand the progression of students who engage in STEM and become equipped for and employed in STEM careers.

Through formal education systems, students are likely to first engage with STEM subjects in kindergarten and continue until they graduate from high school, college, or graduate school. Through informal education systems, students explore and deepen their STEM knowledge, interests, and career aspirations. The STEM pipeline describes the ways in which students develop STEM interests and career aspirations in both formal and informal educational environments. The research demonstrates that students are more likely to engage in the STEM pipeline when they have:

- High test scores (Schneider, Swanson, & Riegle-Crumb, 1998);
- High GPAs (Ware & Lee, 1988);
- Rigorous high school curriculums (Adelman, 2006); and
- Personal interest in STEM (Federman, 2007), particularly middle school interest in pursuing a STEM career (Maltese & Tai, 2011; Tai, Liu, Maltese, & Fan, 2006).

It is important to note that there are likely multiple pathways in which students can pursue STEM (Maltese, Melki, & Wiebke, 2014). Once students connect to the STEM pipeline they are more likely to become STEM professionals. These promotive factors enable students to engage and persist in the STEM pipeline. Furthermore, these findings suggest that there may be optimal times in which to engage K-12 students in STEM education. Unfortunately, certain groups of students are more likely disengage from the STEM pipeline because of leaks in the system.

Leaks in the STEM Pipeline

In the United States, the STEM pipeline is considered "leaky" as many students disengage from STEM at various points during their lives (Alper, 1993; Lyon, Jafri, & St. Louis 2012). In particular, women, Latinos and African Americans are more likely to disengage from the STEM pipeline. For example, women remain underrepresented in STEM careers even though they comprise almost 50% of the working population. The U.S. Census Bureau (2013) found that in 2011, only 26% of STEM professionals were women, compared to 74% who were men. Such trends contribute to gender-based equity issues as STEM positions typically provide higher pay and greater job security compared to other types of employment (Hill, Corbet, & St. Rose, 2010).

Hispanic and African American groups are also underrepresented in STEM positions. According to the U.S. Census Bureau (2013), Hispanics made up 14.9% of the U.S. workforce in 2011, but only held 6.5% of all STEM positions. Similarly, African Americans held 10.8% of total jobs, but only held 6.4% in STEM positions. It is evident that there are disproportionate percentages of women, Hispanics, and African Americans pursuing STEM careers when compared to their

While Male counterparts. This leaky STEM pipeline represents a major problem, as there is an increasing need for STEM professionals in the U.S.

To understand how the leaky pipeline problems can be resolved, it is important to identify the factors that contribute to students leaving the STEM pipeline. The literature indicates that students are more likely to disengage from the STEM pipeline if they:

- Are in one or more of the underrepresented groups in STEM (Jakubowski, Freeman, & Billig, 2011);
- Do not have a preference for a STEM career (Maltese & Tai, 2011);
- Do not have interest in a science career by eighth grade (Maltese & Tai, 2011);
- Do not think science would “be useful in their future” by eighth grade (Maltese & Tai, 2011);
- Do not plan to major in a STEM field by 12th grade (Maltese & Tai, 2011); and
- Do not develop interest in STEM in middle school, high school, or freshman or sophomore year of college (Maltese et al., 2014).

Taken together, these findings suggest that students are more likely to disengage from the STEM pipeline when they fail to develop interests and career aspirations in this area. In addition, there appears to be pivotal times during which students are more likely to engage with or disengage from the STEM pipeline (a topic that will be discussed later in the report).

Fixing the Leaky STEM Pipeline

The leaky STEM pipeline is recognized in the U.S. as a problem that needs to be addressed. From a policy perspective, over the past decade, increasing calls to action and policies have been implemented to support STEM education and programming. Funding to support these initiatives has also been made available. The following timeline highlights key events that have been implemented to address this issue:

- 2006—The Bush administration proposes funding to support STEM academics and resources (American Library Association, 2013).
- 2007—The America Competes Act is signed, making it the law to focus on STEM education (American Library Association, 2013). The act was reauthorized in 2011.
- 2010—The U.S. Department of Education sets forth initiatives to increase the percentage of the population with a postsecondary degree and move closer to closing the achievement gap for underrepresented populations. One of the Department of Education’s goals and recommendations regarding STEM education was to: “Use advances in learning sciences and technology to enhance STEM

learning and develop, adopt, and evaluate new methodologies with the potential to inspire and enable all learners to excel in STEM” (p. xvi). Additionally, the Department of Education emphasized utilizing informal learning outside of traditional school hours based on students’ interests to increase their motivation in STEM learning.

- 2011—The National Research Council (2011) sets forth three goals for STEM education in the U.S. that revolve around expanding the pursuit of advanced STEM education and degrees, expanding the workforce of individuals prepared in STEM, and increasing all students’ literacy in STEM fields.
- 2011—The Young Adult Library Services Association (2011) creates a national research agenda that focuses on the how libraries can provide informal education for young adults and defines the impact that libraries can make.
- 2013—The Committee on STEM Education creates a five-year strategic plan for STEM education. This strategic plan outlines the following five priorities for STEM education investment: 1) improve STEM instruction, 2) increase and sustain youth and public engagement in STEM, 3) enhance STEM experience of undergraduate students, 4) better serve groups historically underrepresented in STEM fields, and 5) design graduate education for tomorrow’s STEM workforce (Committee on STEM Education, 2013).

STEM-focused programming is gaining momentum as funding for STEM education is increasing in formal and informal education settings. Specifically, various STEM initiatives are being supported through grants, including federal and state government grants, as well as grants from foundations and nonprofits. This focus on STEM programming can be seen in the increased funding provided to 21st Century Community Learning Centers,¹ which provide federally-funded afterschool² programs. From 1994 to 1998, funding for these centers rose to

¹ The Framework for 21st Century Learning has supported educational initiatives across the U.S, with a special emphasis on STEM education (<http://www.p21.org/about-us/p21-framework>). Through this framework, educators can support students in the following skills: 1) life and career development, 2) learning and innovation, 3) information, media, and technology, 4) key subjects, and 5) 21st century themes. New methods and paradigms using this framework are being established across the nation to promote education. In the context of STEM education and programming, the Framework for 21st Century Learning provides a foundation in which to promote best and promising STEM educational practices.

² The term "afterschool" in this report represents learning that occurs before school, afterschool, and during the summer (Afterschool Alliance, 2011). The terms "out-of-school time" and "afterschool" are interchangeable for this report.

\$40 million, and increased to \$1.2 billion by 2016 (Afterschool Alliance, 2016). In 2010, STEMgrants.com began publishing a free guide to funding opportunities in STEM education, which it updates multiple times each year (STEMgrants.com). Additional information on STEM funding, particularly for informal education programs, has been made available by the Afterschool Alliance (American Library Association, 2013).

Since 2013, resources have been developed and made available to create, implement, and evaluate STEM programming and education in a variety of settings, including formal and informal educational systems. Formal education represents learning that takes place in schools and universities, typically through lectures, class discussions, and classwork. Informal education provides learning that takes place outside of formal education environments in places like museums, zoos, and aquariums. Informal education occurs through activities such as afterschool programs, field trips, and camps in which learning is the intended outcome. New and innovative programming for STEM education are also being developed. Solutions are taking various forms, including the creation of STEM-specific schools, STEM-related competitions (e.g., robotics competitions, video game challenges) and STEM fairs. These resources have helped students engage and persist in the STEM pipeline.

However, formal education alone may not be enough to keep students in the STEM pipeline or prepare them to pursue postsecondary STEM education (Community for Advancing Discovery Research in Education, 2011). For example, nearly 30% of students entering college are unprepared to take freshman-level science and math courses, as evidenced by remedial course enrollments (National Science Board, 2007). Students need additional support in developing their interest and abilities in STEM subjects outside of traditional formal education. Informal STEM education can supplement formal educational experiences, which can lead to increased interest and engagement in STEM fields.

Research indicates that students engaged in afterschool programming have a higher likelihood of being interested in STEM careers (Afterschool Alliance, 2014). A recent report by the Afterschool Alliance (2014) indicates that the demand for afterschool programming has increased in the past decade as an estimated 19.4 million children would participate in afterschool programming if they could, according to their parents. Additionally, 69% of parents report that afterschool programming provides their child with STEM learning opportunities (Afterschool Alliance, 2014). Furthermore, learning initiatives outside of school hours have the potential to make a great impact on students and their engagement in STEM, as time spent in school represents less than five percent of students' time (Falk & Dierkling, 2010). However, many students remain underserved in STEM education and programming due to a complex array of social, cultural, personal, and psychological factors. The following section describes

how equity and access issues prevent historically underrepresented students from pursuing and persisting in the STEM pipeline.

Equity, Access, and the STEM Pipeline

All students deserve equity and access in education that includes strong teachers and school leaders, rigorous course offerings, high standards, robust enrichment opportunities through formal and informal education, safe environments in which to learn, and support from caring adults. Historically underrepresented groups such as girls/women, ethnic minorities, students from low-income households, and students with disabilities are more likely to disengage from the STEM pipeline (Gilmartin, Li, Aschbacher, & McPhee, 2005). These students face a number of challenges and obstacles because of their social identities such as gender, race, and class. This educational inequality influences how such students engage in STEM, both in formal and informal education settings. As a result, these students are less likely to pursue STEM careers and join the STEM workforce. Formal education is not enough to address the leaky STEM pipeline.

There is an abundance of research that has examined why certain students are more likely to disengage from STEM. This is especially true of gender research. However, few studies have investigated how multiple social identities influence students' decision to pursue and persist in STEM educational pathways. Furthermore, the majority of research has focused on STEM equity and access issues in formal settings. Therefore, it is important to understand why historically underrepresented students disengage from the STEM pipeline, when this occurs, and how equity and access issues contribute to this problem.

The section examines equity, access, and the STEM pipeline through the lens of Social Identity Theory (Tajfel & Turner, 1979). This theory describes how individuals form a sense of who they are based on their group membership. According to Tajfel and Turner (1979), individuals cognitively process in-group or out-group membership (i.e., "us" versus "them") through three stages: 1) social categorization (i.e., the process of determining which group you or someone else belongs), 2) social identification (i.e., the process of identifying more strongly with a specific social group), and 3) social comparison (i.e., comparing ourselves to other groups to promote self-concept or self-esteem). This theory also describes how individuals form stereotypes or oversimplified or exaggerated generalizations of a particular person or group. In the context of this report, Social Identity Theory offers one explanation for why underrepresented students disengage from STEM – they may not identify with STEM or form a STEM identity. For instance, a number of studies (Aschbacher et al., 2010; Carlone & Johnson, 2007; Gilmartin et al., 2005) have examined science identity as it relates to student engagement and disengagement from STEM fields. These studies demonstrate the importance

of science identity, an extension of Social Identity Theory, in promoting or hindering the STEM pipeline of historically underrepresented students.

Girls and STEM

Despite recent increases of women in biology and engineering fields (Hill et al., 2010), the well-documented gender gap in STEM education and career fields persists (Brotman & Moore, 2008; Maltese & Tai, 2011; Subramaniam, Ahn, Fleischmann, & Druin, 2014). Factors contributing to this gap include negative stereotypes and self-concepts, lack of STEM opportunities, and other demographic factors such as race and socioeconomic status. This section highlights these factors and provides some research-based recommendations to address the gap.

Negative gender-based stereotypes are a common barrier for girls in STEM, particularly for their engagement with STEM education and career aspirations (Hanson, 2007). Young students, especially boys, believe that biological sciences are “for girls” while physical sciences (e.g., physics, chemistry) are “for boys” (Brotman & Moore, 2008). This idea is reinforced by parents who believe that science is less important for girls than for boys, and this contributes to this educational disparity (Brotman & Moore, 2008). Societal stereotypes of girls’ roles also impact engagement in the STEM pipeline as beliefs of femininity and gender image expectations seem incompatible with STEM success (Brickhouse, Lowery, & Schultz, 2000; Grossman & Porche, 2014). Such external stereotypes present challenges for girls interested in pursuing STEM education and careers. In addition, these negative stereotypes and experiences may prevent girls from forming positive STEM identities, which is critical to persistence in STEM careers (Brotman & Moore, 2008).

Negative stereotypes of girls in STEM are not only external, however, as girls’ self-concepts of their abilities in STEM subjects are lower than the self-concepts of boys (Brotman & Moore, 2008; Simpkins, Davis-Kean, & Eccles, 2006). The perception that girls lack abilities in STEM fields is another obstacle that prevents girls from pursuing STEM subjects and careers (Grossman & Porche, 2014). These low self-concepts persist despite girls and boys holding similar values toward STEM subjects (Simpkins et al., 2006) and the fact that girls experience success in STEM subjects equal to or greater than boys (McCreedy & Dierking, 2013). Part of the problem is that girls may have fewer opportunities to engage in STEM than boys, particularly in regard to extracurricular activities (Brotman & Moore, 2008). As a result, girls are underserved by STEM education and programming and are less likely to engage in the STEM pipeline.

Factors such as race and socioeconomic status are also important to consider when discussing girls in STEM, as different subgroups of girls experience their own unique barriers to STEM education and career aspirations (Bianchini, Cavazos, & Helms, 2000). While some STEM

barriers may be shared by all girls, the literature suggests that research on white girls may not generalize to girls of different racial and ethnic backgrounds (Hanson, 2007). For example, African American girls feel less welcome in STEM subjects, particularly science, than white girls do (Hanson, 2007), and Latina girls feel more pressure to act in traditional Hispanic female roles (Aschbacher et al., 2010). Girls from low socioeconomic status (SES) backgrounds feel more limited in their future goals and identity choices than girls from higher SES backgrounds (Aschbacher et al., 2010). Such research demonstrates that a multicultural lens that considers differing economic backgrounds may be necessary when gender-related barriers in STEM are identified and solutions are implemented (Hanson, 2007).

In an effort to help girls overcome barriers in the STEM field, the Institute of Education Sciences (Halpern et al., 2007) makes the following recommendations:

- Empower girls' self-concepts of their abilities to engage in and contribute to STEM;
- Change girls' perceptions of STEM careers as less significant than careers in other fields; and
- Support girls' interest in STEM through access.

Similarly, Campbell, Jolly, and Perlman (2004) recommend focusing on engagement, capacity, and continuity (ECC) to address the underrepresentation of women in STEM fields. These researchers provide suggestions to educational policymakers, sponsors, curriculum/program developers, evaluators, district/school administrators, teachers, and museums and other informal science institutions in how they can incorporate the ECC trilogy to support girls in STEM. Brickhouse et al. (2000) also suggests that when girls believe they are good at science and feel included in science communities, this increases their engagement in science. Further, when family members value, advocate, and have an interest in science-related topics, this positively influences both boys and girls in their science career aspiration (Gilmartin et al., 2005). As interest in STEM subjects often declines when girls enter middle school (Brotman & Moore, 2008), strategies targeting younger populations may better address disparities in girls in the STEM pipeline. While the research suggests a need for a multicultural lens in the creation of solutions for girls in STEM, specific practices for girls/women of different racial, ethnic, and SES backgrounds need to be further researched in the literature.

Ethnic Minorities and STEM

While females are underrepresented in STEM fields, individuals from African American and Hispanic backgrounds may face additional barriers in STEM education and employment. For instance, research suggests that Hispanic and African American children begin school behind their white and Asian peers, even at the kindergarten level (Gándara, 2006). Additionally,

advanced math and science courses in high school are less accessible for students from African American and Hispanic backgrounds (Hill et al., 2010). Thus, while students of color are interested in pursuing STEM careers; they are more likely to drop out during postsecondary education (Anderson & Kim, 2006). Adelman (2006) suggests these outcomes are related to economic factors and poor academic preparation.

Tsui (2007) explains how the disproportionately low participation of ethnic minorities in STEM is the result of cultural (e.g., social expectations), structural (e.g., historical laws and regulations), and institutional barriers (e.g., discriminatory policies and practices). In particular, these groups have less access to quality STEM education and programming due to their socioeconomic status and racial status (May & Chubin, 2003). In STEM fields specifically, stereotypes and discrimination create barriers for Hispanic and African American students. For instance, certain stereotypes question the intelligence of people from Hispanic and African American backgrounds (Fisher, Wallace, & Fenton, 2000). Perceptions of barriers and lack of opportunities may also prevent ethnic minorities from pursuing STEM careers. In a meta-analysis conducted by Fouad and Byars-Winston (2005) that focused on the cultural context of career choice, these researchers found that race and ethnicity did not influence career choice; however, there were significant differences in how members of specific ethnic and racial groups perceived career opportunities and barriers. Specifically, minority racial and ethnic groups perceived fewer career opportunities compared to white individuals (Fouad & Byars-Winston, 2005). This educational disparity may also be related to factors outside of schooling such as lack of or inadequate: health care, nutrition, stable housing, neighborhood environments, and adults who can serve as role models providing support and guidance (Gándara, 2006). Therefore, such barriers may prevent ethnic minority students from persisting in the STEM pipeline.

Several additional barriers have been described to explain why fewer ethnic minorities pursue STEM fields. For example, Museus, Palmer, Davis, and Maramba (2011) defined eight factors that prevent minorities' success in formal STEM education:

1. School district funding disparities;
2. Tracking into remedial courses;
3. Underrepresentation in advanced placement (AP) courses;
4. Unqualified teachers;
5. Low teacher expectations;
6. Stereotype threat;
7. Oppositional culture; and
8. Premature departure from high school.

Even accessing informal STEM education is a barrier. According to the Afterschool Alliance (2014) 60% of African American students and 57% of Hispanic youth would participate in afterschool programming if they could. Unfortunately, barriers such as cost, lack of a safe way to get to and from afterschool programs, and lack of afterschool programs prevent low-income African American and Hispanic families from enrolling their children in afterschool programs. Despite these barriers, existing programs have not been found to successfully close this achievement gap for Hispanic students (Gándara, 2006). However, qualitative research shows that Hispanic women in senior STEM positions received positive social support in their pursuit of STEM careers, which may have been instrumental in their success (Subramaniam et al., 2014). While these findings are specific to the Hispanic population, they may provide insight and support for solutions for other underrepresented minority groups that face similar barriers in STEM. Tsui (2007) outlines 10 major intervention strategies to increase diversity in STEM fields of undergraduate students, recommending an integrated approach when working with underrepresented students. The list below highlights Tsui's (2007) strategies:

1. Summer bridge;
2. Mentoring;
3. Research and experience;
4. Tutoring;
5. Career counseling and awareness;
6. Learning center;
7. Workshops and seminars;
8. Academic advising;
9. Financial support; and
10. Curriculum and instructional reform.

While these strategies focus on students beyond K-12, many of the suggestions overlap with what has been recommended with K-12 students. For example, the strategies emphasize how these students need additional education (e.g., summer bridge, research and experience) and support (e.g., mentoring, tutoring) outside of formal education. Further research is needed to understand the characteristics of STEM education and programming that can address the STEM pipeline issues for ethnic minority students.

Low Socioeconomic Status (SES) Students and STEM

Students with a low socioeconomic status (SES) are another underrepresented group who are more likely to disengage from the STEM pipeline. These students are often from minority households (Pew Research Center, 2014b) and face similar barriers as ethnic minority groups. In fact, 2013 data suggests that the median wealth of white households was 13 times greater than

the median wealth of black households and 10 times greater than the median wealth of Hispanic households (Pew Research Center, 2014b). Students from low-income households were six times more likely to drop out of high school (National Center for Education Statistics, 2011).

Lyon et al., (2012) suggest that low-income students of color are more likely to be excluded from or disengaged from STEM pipeline at important moments in middle and high school. Part of the problem may be that in addition to many of the barriers that ethnic minority students face, low-income students have less qualified science instructors (i.e., teachers with at less than three years of experience teaching science), a trend that was observed for eighth-grade students from low-income households (National Science Foundation, 2011). Schools that serve more low SES students are less likely to offer any mathematics courses above Algebra II (Tsui, 2007), which puts low SES students at a disadvantage because engaging in higher-level math classes increases the likelihood that a student will pursue a STEM major or career (Federman, 2007). In a study conducted by Aschbacher, Ing, and Tsai, (2014) low-income students were more likely to lack confidence in their science abilities and were more likely to identify in a "science is not me" category compared to their high SES peers (60% vs. 47%, respectively). Clearly, because of the factors outlined above, low SES students may be less likely to persist in the STEM pipeline.

According to the Afterschool Alliance (2014), demand for and participation in afterschool programming among low-income households is higher than higher-income students; however, nearly 50% of students not participating in afterschool programming would be enrolled if they could. This finding suggests that there is a large unmet need for afterschool programming for low-income students. These findings are true of many minority groups (e.g., Latino, Native Americans) as well, so it can be difficult to delineate between STEM findings and general trends for these populations. That is why it is important to view each group from the Social Identity Theory lens —one in which students are members of multiple groups simultaneously and these social identities influence their views, values, and experiences.

Students with Disabilities and STEM

Research that has examined why students with disabilities disengage from the STEM pipeline is limited (National Science Foundation, 2011). This is unfortunate because such youth are less likely to take advanced science or mathematics courses and pursue higher education (Fancsali, 2002). Students with disabilities are also more likely to drop out of high school (National Science Foundation, 2011). Additionally, students with disabilities perform poorly on standardized tests compared to their peers without disabilities (Marino, 2010). As a result, students with disabilities are less likely to enter the STEM workforce even though many are

capable of making a contribution to the field (Leddy, 2010). Girls with disabilities are especially vulnerable because they are less likely to have science and mathematics experiences.

Students with disabilities may lack the skills and confidence to pursue and persist in STEM education. In a seminal article by Dalton, Morroco, Tivnan, and Mead (1997), the authors found that students with disabilities who participated in science activities:

- Had limited prior knowledge;
- Were reluctant to pose questions;
- Were less likely to have a plan for solving problems;
- Struggled to implement teacher recommendations;
- Had difficulty with inductive and deductive reasoning; and
- Seldom transferred knowledge to other contexts.

That is why personal factors such as self-efficacy, self-determination, and self-advocacy skills are necessary ingredients to instill in youth with disabilities to promote their interest and persistence in STEM education (Bremer, Kachgal, & Schoeller, 2003). Bremer and colleagues (2003) provided the following tips for families and professionals to promote self-determination in students with disabilities:

- Promote choice making;
- Encourage exploration of possibilities;
- Promote reasonable risk taking;
- Encourage problem-solving;
- Promote self-advocacy;
- Facilitate development of self-esteem;
- Develop goal setting and planning; and
- Help youth understand their disabilities.

While these tips may not directly relate to STEM education and persistence in the STEM pipeline; they provide an approach through which to support youth with disabilities. Basham and Marino (2013) also suggested applying a Universal Design for Learning approach to facilitate STEM learning for students with disabilities in which teachers provide an engaging learning environment through instructional practices (e.g., curriculum standards and goals, instructional materials and tools, methods to assess outcomes) and modern technology). Additionally, Basham, Israel, and Maynard (2010) have recommended commitment to and accountability for, STEM for all educators. What this means is building K-12 STEM capacity through curriculum and instruction that is accessible for all students, strategic partnerships that

support students with disabilities, access to research for teachers and students, and support for families and caregivers. While these recommendations may be useful in formal settings, less is known about how to engage youth with disabilities in informal education settings.

The Informal Education Landscape

As the United States is facing scarcity in qualified STEM professionals, informal education³ may be an avenue through which students can further engage in STEM education to supplement learning in schools. Informal education is described as an environment that promotes and facilitates STEM education and programming outside of formal education. While formal educational settings emphasize and evaluate student content knowledge through classroom formatting and standardized testing, informal education settings have been found to promote sustained interest in STEM subjects (Clewell & Campbell, 2002; Henderson & Dancy, 2011). According to the Afterschool Alliance (2011), interest in STEM subjects provides an important indicator of whether students will pursue careers in STEM fields. Supporting informal education as a potential solution to the STEM pipeline problem, in 2011, the President's Council of Advisors on Science and Technology selected informal education as a funding priority (PCAST, 2010).

Informal education has a long-standing history in the United States, serving as the foundation upon which the formal education system was built. In the late 18th century, libraries, churches, and museums were the driving force of public education, supported by movements encouraging public lectures, experiments, and scientific entertainment (Bell et al., 2009). Informal education was also found in apprenticeships for trades and through family learning in an agrarian society (Barab & Hay, 2001). As the responsibility for education shifted from families to schools with the advent of new technology, children engaged less frequently in the same apprenticeship and agrarian experiences as their ancestors (Bell et al., 2009). Today, the institutions of informal education still provide educational experiences for people of all ages.

³ Other terms used to describe informal education are: "non-formal learning," "incidental learning," and "informal learning." Non-formal learning has been defined as an educational activity that is organized and systematic, occurring outside of formal education to aid the learning of specific subgroups (Sevdalis & Skoumios, 2014). Incidental learning has been presented as a type of informal learning that occurs as a byproduct of an activity where the learner may or may not be aware that learning has taken place (Marsick & Watkins, 2001). Since informal learning and informal education are similar, for the purposes of this report, informal education has the intended outcome of learning; whereas, informal learning can take place anywhere, anytime, and without learning as an intended outcome.

Informal education occurs across a variety of settings (e.g., informal education institutions, technology platforms) and at differing levels (e.g., afterschool programs, field trips, summer camps). Both formal and informal education tend to be intentional. In other words, both of these approaches are structured in a way so that the intended outcome is learning. When comparing informal and formal education, three distinctions are commonly made: 1) the educational setting, 2) the amount of structure, and 3) the person responsible for ensuring learning occurs. While formal education is often highly-structured (i.e., taking place within a classroom) with the educator responsible for learning, informal education is often unstructured or less-structured (i.e., outside of a traditional classroom setting), with the learner holding the responsibility (Marsick & Watkins, 2001). This report focuses on informal education that takes place in unstructured informal education institutions (e.g., museums, zoos, aquariums) and within structured or semi-structured programs (e.g., afterschool programs, out of school).

The Afterschool Alliance (2013) recommends the following three developmental outcomes for youth engaged in informal STEM education:

1. Interest in STEM and STEM learning activities;
2. Capacity to productively engage in STEM learning activities; and
3. Value placed on the goals of STEM and STEM learning activities.

These three outcomes – interest, capacity, and value in and for STEM are recognized as the overarching goals of informal STEM education in this report. The following section reviews the literature on conceptual models and theories that support informal education, informal education focusing on specific contexts for informal education, established informal education approaches, equity and access considerations for K-12 students, promising informal STEM education programs, and best and promising practices for informal STEM education.

Frameworks that Support Informal Education

Several frameworks have been proposed and examined within the context of informal education and STEM. These frameworks which represent theories and conceptual models have been utilized to create, support, and examine informal education and programming. Specifically, the following frameworks were identified in the literature review include: 1) Social Learning Theory, 2) Constructivist Theory, 3) Socio-Cultural Theory, and 4) Falk's Contextual Learning Model. Each of these frameworks recognizes the learner as responsible for learning rather than the educator. Additionally, several of these framework recognize the importance of the social aspects, cultural influences, and physical contexts of learning. While each of these frameworks is unique, the order in which they are presented represents how they build upon one another to explain and support learning in informal education environments.

Social Learning Theory

Social Learning Theory (Bandura, 1971) emphasizes how individuals learn through observation or direct instruction that occurs in social contexts. The key tenets of Social Learning Theory describe how learning is a cognitive process that occurs by observing a behavior and the consequences (i.e., good or bad) associated with performing that behavior. According to Bandura (1977) learning involves: 1) observation and making decisions from observations, 2) reinforcement, and 3) the idea that the learner is not passive, but that they learn from their cognition, environment, and behavior. Informal education emphasizes Social Learning Theory through modeling behavior, reinforcing learning, and supporting social interaction and participation of learners. This theory emphasizes the activities and interactions that take place while learning, rather than the content of the learning itself (Brown & Adler, 2008). By recognizing the social aspects of learning, informal education can provide supplementary STEM engagement in ways beyond the capacity of formal education.

Constructivist Theory

The Constructivist Theory (Piaget, 1977) supports distinct views about knowledge and the focus of learning. Proponents of this theory recognize a lack of external “knowledge” and rather view knowledge as the meaning that learners construct, both individually and socially (Eldeson, 2001; Hein, 1991). Therefore, the focus of learning in the Constructivist Theory is not on the content, but on the act of learning itself (Hein, 1991). This theory recognizes the social aspect of learning, similar to Social Learning Theory. For informal settings, the Constructivist Theory can provide support for the process of learning, rather than content. Allen (2004) describes how in the context of museums, one in which there is a diverse audience, visitors seek entertainment, free-choice activities, the ability to follow their own interests, do their own inquiry, and make their own meaning from what they experience. However, museums and other informal education institutions are expected to be respected educational institutions where people spend their time and learn something from their visit. This challenge may be difficult for informal education institutions to overcome, encouraging the use of other theories instead of or in addition to the Constructivist Theory.

Socio-Cultural Theory

Socio-Cultural Theory (Vygotsky, 1931/1997) integrates social and cultural aspects of learning by acknowledging the cultural context within which learning takes place. This theory examines the social aspects, cultural artifacts, and tools used by learners when interacting with others (Vartiainen & Enkenberg, 2013). Learning in STEM, then, is not siloed, but rather situated within the cultural and social issues of the time in which the learning takes place (Lemke, 2001). The Socio-Cultural Theory supports learning in informal environments by encouraging participation in cultural activities in contexts and with tools specific to the informal environment (Vartiainen

& Enkenberg, 2013), particularly in museums. As Vartiainen and Enkenberg (2013) discuss, Socio-Cultural Theory supports the construction of interactive learning interventions that encourage people to create and share knowledge with one another by asking questions. The Socio-Cultural Theory also supports the use of different types of technologies to support the learning process within informal education and for technology use to be a competency of learning (Vartiainen & Enkenberg, 2013).

Falk's Contextual Model of Learning

Falk's Contextual Model of Learning (Falk & Storkdieck, 2005) provides a framework for understanding learning within informal settings of free choice. This theory is driven by three hypothetical contexts an individual interacts within: 1) personal, 2) sociocultural, and 3) physical contexts. Each of these contexts is dynamic, changing over an individual's lifetime, and are avenues through which individuals learn (Falk & Storkdieck, 2005). To further understand each of these three contexts, Falk and Storkdieck (2005) proposed the following 12 factors that influence an individual's learning experience in a free-choice environment:

Personal context:

1. Visit motivation and expectations;
2. Prior knowledge;
3. Prior experiences;
4. Prior interests;
5. Choice and control;

Sociocultural context:

6. Within group social mediation;
7. Mediation by others outside the immediate social group;

Physical context:

8. Advance organizers;
9. Orientation to the physical space;
10. Architecture and large-scale environment;
11. Design and exposure to exhibits and programs; and
12. Subsequent reinforcing events and experiences outside the free-choice informal education setting.

For informal, free-choice, education settings, Falk's *Contextual Model of Learning* (2005) can serve as a framework through which visitor educational experiences are designed and developed. This model also provides contexts for which evaluation of educational experiences

can be created. Taken together, each of these theories sheds light on how people learn in different informal education environments. Unfortunately, more research is needed to test and examine the utility of these theories in informal education learning environments, especially for STEM.

Specific Contexts for Informal Education

Informal education takes place in a variety of contexts outside of school hours, including in institutions of informal education, during afterschool programs, in summer camps, and on technology platforms. To understand how this learning takes place location-, program-, and platform-specific contexts are described below. Each of these contexts emphasizes informal learning in structured and semi-structured environments. Specifically, these contexts describe environments that are more likely to provide informal STEM education to K-12 students.

Institutions of Informal Science Education

Institutions of informal science education or science-rich institutions represent a type of location-specific informal learning environment. These institutions exemplify places that promote science learning for all people, regardless of age or background. Typically, institutions of informal science education include science museums, aquariums, zoos, nature centers, planetariums, botanical gardens, and other establishments dedicated to community science learning. While these learning institutions are typically free-choice settings, they may also provide interactions for students that are not free choice, as many schools collaborate with these settings to provide structured experiences. For example, Inverness Research Associates (1996), found that a least 75% of surveyed institutions (N = 440) offered school field trips that were structured. However, opportunities for further collaboration between formal and informal education settings may be underutilized (Phillips, Finklestein, & Wever-Frerichs, 2007). Additionally, school field trips can stifle the impact of these institutions, as learning may be limited, providing less free choice in a school group setting (Vartiainen & Enkenberg, 2013).

Institutions of informal science education can make great contributions toward learning scientific phenomena (Vartiainen & Enkenberg, 2013). Indeed, Bell and colleagues (2009) presented six strands to describe how institutions of informal science education can facilitate learning. Specifically, informal science education that is offered in free-choice learning environments can help students:

1. Develop an interest in science;
2. Understand scientific knowledge;
3. Engage in scientific reasoning;
4. Reflect on science;

5. Engage in scientific practices; and
6. Identify with the scientific enterprise.

These six strands can serve as a framework within which science and other STEM learning can be organized and assessed (Bell et al., 2009). Indeed, the six strands are also closely aligned with the overall goals in informal STEM education (i.e., interest, capacity, value). Students who believe they can do science and value science are more likely to express an interest in STEM careers (Aschbacher et al., 2014). Therefore, programs that emphasize the six strands may be more likely to connect students to the STEM pipeline.

Program-specific

Informal STEM education takes place outside of science-rich institutions as well, typically revolving around specific programming designed for learners. Afterschool programs provide students with organized activities outside of school hours such as before school, afterschool, or during the summer (Hartman, 2011). Student activities in afterschool programs range from sports and recreation, to academic support, mentoring, and youth development. Afterschool programming has been found to improve both academic outcomes (e.g., improved school attendance and engagement with learning, improved test scores and grades, gains for students at greatest risk) and behavioral outcomes (e.g., keeping children safe, improvement in children's self-concept and decision-making, helping working families and encouraging parental participation, helping keep kids healthy, reducing truancy and improving behavior in school) for students enrolled in such programs (Afterschool Alliance, 2015). For the purposes of this report, afterschool programs will refer to programs that intentionally involve students in one or more aspects of STEM.

Afterschool programs employ various methods of engaging students in STEM learning, including clubs, apprenticeships, summer camps, and STEM contests and fairs. Each method can engage students in STEM learning at different levels. For example, STEM contests can engage students in varied aspects of STEM, allowing youth to become more deeply involved in the subject matter of the contest and engage in creative problem-solving with other like-minded students (PCAST, 2010). Engaging with high-quality afterschool STEM programs have several proven benefits such as improved attitudes toward science, pursuit of science-related occupations, and engagement in lifelong science learning (Bell et al., 2009). The Afterschool Alliance (2011) described the following outcomes related to STEM afterschool programming:

1. Improved attitudes toward STEM fields and careers;
2. Increased STEM knowledge and skills; and
3. Higher likelihood of graduating and pursuing a STEM career.

These outcomes also closely align with the overall goals in informal STEM education (interest, capacity, and value).

Platform-specific

Informal STEM education may also take place through media, including television, social media sites, and Internet programming (Bell et al., 2009; Evans, Lopez, Maddox, Drape, & Duke, 2014; Evans, Won, & Drape, 2014; Sacco, Falk, & Bell, 2014). While media can be a stand-alone platform for informal education, many informal institutions and programs utilize media as a part of their education programs. Unfortunately, the impacts of many forms of informal STEM media have not been evaluated (Bell et al., 2009). Some research suggests that pedagogical implementation is as crucial to the success of technology-based learning as the resources and tools available (Vartiainen & Enkenberg, 2013). As a result, more research is needed regarding platform-specific informal STEM education.

Established Informal Education Approaches

Traditional education in a formal setting has been based on the notion that knowledge is transferred from teachers to learners (Brown & Adler, 2008), supporting the traditional method of lecture-based education. In fact, society still recognizes formal education as the “dominant system of learning” in the United States (Sevdalis & Skoumios, 2014). Recently, some approaches have emerged that amend this view to include the role of learners in the educational process, resulting in learner-centered approaches to education. These approaches include inquiry-based education, problem-based learning, and makerspaces. Each of these approaches endorses the learner as responsible for the development of his/her education and encourages active student engagement in learning content.

Inquiry-based education

A framework set forth by Minner, Levy, and Century (2009) suggests that inquiry-based education, at least in the realm of science, has three aspects: 1) presence of science content, 2) student engagement with science content, and 3) responsibility for learning. In this approach, students utilize methods of professional science to understand and construct knowledge around certain phenomena through developing and testing hypotheses to answer a specific question (Pedaste et al., 2015). Learners both actively engage in the process of learning and are responsible for their own learning in inquiry-based education. While outcomes on student learning for inquiry-based education appear mixed (Bell, Blair, Crawford, & Lederman, 2003), aspects of inquiry-based learning such as responsibility for learning being driven by students may improve the learning of content (Minner et al., 2009). Edelson (2001) also suggests that designers seeking to support inquiry-based science education should create programs that motivate (i.e., design activities that create a demand and elicit curiosity), construct (i.e., design

activities that provide direct experience and receive communication through the activity), and refine (i.e., help users apply their knowledge in meaningful ways and provide opportunities for users to reflect on their experiences).

Problem-based learning

Problem-based learning is supported in the literature as a strategy that supports STEM, specifically because it reflects the processes of engineering design (Evans et al., 2014a). This type of learning is a constructionist method that allows learners to solve meaningful problems to promote active learning (Evans et al., 2014a). Many informal education settings are utilizing problem-based learning to make content engaging for youth (Evans et al., 2014a). Through problem-based learning, students are able to generate solutions to real problems by applying learned content knowledge (Evans et al., 2014b).

Makerspaces

The Maker Movement is another approach in informal learning that promotes making as a vehicle of learning (Bevan, Gutwill, Petrich, & Wilkinson, 2014; Institute of Museum and Library Services, 2014b). Making is creative production that allows learners to actively engage in STEM disciplines, fostering creativity and innovation (Bevan et al., 2014; Brahms, 2014). Making has been associated with advancing youth entrepreneurship, developing the STEM workforce, and supporting inquiry-based learning (Bevan et al., 2014). The Maker Movement utilizes active and problem-based learning approaches, enabling learners to engage in creative production and problem-solving based on their interests (Brahms, 2014). Learners involved in the Maker Movement are able to learn through hands-on experiences that would be otherwise difficult to learn in formal education settings. Makerspaces provide the location for making activities that can promote STEM learning. This movement is supported by cultural trends in do-it-yourself communities, as well as technological advancements. One branch of the Maker Movement is tinkering, the open-ended creation of technological objects or installations (Bevan et al., 2014). This approach enables learners to solve real-world problems while developing their object or installation. Both making and tinkering allow learners to collaborate with one another and pursue STEM areas that interest them (Institute of Museum and Library Services, 2014b).

Equity and Access Considerations for K-12 Students

As equity and access are forefront concerns for solutions to the STEM pipeline problem, it is important to recognize the role of informal education in promoting STEM equity and access for K-12 students. As Hartman (2011) noted, one of the factors contributing to the achievement gap is how students spend their time when they are not in school (i.e., spending time in afterschool activities vs. watching television). Informal education, particularly in STEM, can engage students in activities that can mitigate the effects of the achievement gap, promoting

equality in STEM and STEM access. For underrepresented populations in STEM (e.g., girls, ethnic minorities), informal education can improve learning outcomes (National Institute on Out-of-School Time, 2009). Further, the experiences can help students create a connection with STEM subjects (Fancsali & Froschl, 2006).

For all underrepresented groups, certain aspects of informal education may lend better to sustained interest and improved outcomes in STEM subjects. Practices such as including participation in afterschool programs, mentoring, and developing meaningful connections between students and adults have shown positive results (Fancsali & Froschl, 2006; Jakubowski et al., 2011; Lyon et al., 2012; Tsui, 2007). In fact, Lyon and colleagues (2012) describes the importance of moving beyond the barriers that prevent underrepresented groups from seeing themselves as STEM professionals and engaging in the STEM pipeline to design programs that promote educational equity.

While several programs are currently engaging historically underrepresented students in informal STEM education and providing some evidence for improved outcomes, more research is necessary to determine the characteristics specific to these underrepresented populations that would produce effective practices. The Harvard Family Research Project (2004) has identified five barriers to student engagement in afterschool activities:

1. Desire to relax and “hang out” with friends after school;
2. Desire or need to work;
3. Family responsibilities;
4. Boredom or disinterest; and
5. Transportation/safety issues.

These barriers may prohibit students from engaging in informal STEM education activities, particularly afterschool programs. Additionally, such barriers may make it that much more difficult to serve underrepresented groups who already are more likely to disengage from the STEM pipeline. Other barriers that have been found to influence the equity and access of afterschool programming include program tuition and fees, transportation issues, program location, and programs that are inaccessible for youth with disabilities (Scarf & Woodlief, 2000). The following section provides specific considerations for different underrepresented groups as well as strategies to encourage participation and retention in informal education, particularly through afterschool programs.

Girls

According to the Afterschool Alliance (2011), girls and boys are equally represented in afterschool programs, despite women being underrepresented in STEM fields. However, girls

are still underserved by STEM-specific informal education programs (Fancsali, 2002). Fancsali and Froschl (2006) found that girls are more likely to succeed when they have opportunities for leadership and exploration, the ability to explore new ideas, have the opportunity to engage in dialogue with concerned adults and other students, and are equipped with consciousness about gender, race, and class issues. Unfortunately, certain practices such as cooperative learning and hands-on experiences have produced mixed results regarding long-term STEM engagement for women (Fancsali, 2002). Furthermore, the literature is inconclusive regarding best and promising practices and the characteristics of effective programs that support girls in STEM (Greene, Lee, Constance, & Hynes, 2005; McCreedy & Dierking, 2013). Therefore, more research is needed regarding successful informal education STEM programs for girls (Brotman & Moore, 2008).

Ethnic Minorities

According to the Afterschool Alliance (2011), ethnic minority students are more likely to participate in afterschool programs than other groups of students. On one hand, this may indicate that informal education approaches may be well-suited to reach students from underrepresented ethnic backgrounds in STEM fields. On the other hand, ethnic minority students' needs for afterschool programming are not being met (Afterschool Alliance, 2014). Therefore, offering more afterschool programming for ethnic minorities is a necessity. Programs that account for the barriers (e.g., lack of transportation, safety issues in getting to and from afterschool programming, cost of attendance) that ethnic minorities face represent an important best and promising practice (Afterschool Alliance, 2014). In addition, programs need to be offered earlier for this group as interests are being formed (Gándara, 2006). Another solution is to ensure adults in the program provide strong role models and mentors (Clewell & Campbell, 2002; Fancsali, 2002). Furthermore, minority students learn best through hands-on and/or inquiry-based STEM programming and instructional approaches (Clewell & Campbell, 2002). Lastly, according to Fancsali (2002), afterschool programs are more effective when they have a youth development focus that includes high quality staff, experiential activities, and connect with the student's home life.

Low SES

According to the Harvard Family Research Project (2007), students from low socioeconomic backgrounds are less likely to participate in afterschool programs and when they do, they participate less frequently. While this gap in participation rates has decreased over time, students from low socioeconomic backgrounds still engage with afterschool programs less often than their peers (Harvard Family Research Project, 2007). Part of the problem may be that low socioeconomic students have more difficulty accessing these programs due to cost, location, lack of transportation, and other barriers (Afterschool Alliance, 2014). Such findings suggest that informal education settings, particularly those that require a fee for entrance such

as museums, science centers, and zoos, may be less accessible to students from low socioeconomic backgrounds. Practices employed by some programs to ensure equity and access are to provide free programming or free passes or vouchers for students to engage with informal education settings (Afterschool Alliance, 2014).

Students with Disabilities

For students with disabilities, the Universal Design Learning framework (Basham & Marino, 2013) has been presented as a way that educational environments can be structured for engaging all types of learners. According to Basham and Marino (2013), the Universal Design learning framework, which can help students with disabilities, has four elements that are considered critical for learning:

- Clear goals;
- Intentional planning for learner variability;
- Flexible methods and materials; and
- Timely progress monitoring.

While this framework can serve as a foundation for designing learning experiences for all students, it may enhance accessibility particularly for students with disabilities engaging in informal educational environments (Bell et al., 2009). In addition, promoting personal factors such as self-efficacy, self-determination, and self-advocacy for students with disabilities, especially when they are young, can help them develop STEM interests and persevere in the STEM pipeline (Rule et al., 2009).

Promising Informal STEM Education Programs

A number of informal STEM education programs have been evaluated. These programs have demonstrated positive short-term outcomes for students in STEM. However, fewer evaluations have examined the long-term impact of these programs on students and STEM (McCreedy & Dierking, 2013). Given the fact that more research is needed to evaluate best and promising practices in informal STEM education programs, it is difficult to identify evidence-based programs. Thus, the following are examples that provide promising informal STEM educational programs, including a brief description of each program, settings in which program education occurs, approaches utilized by the program, and results published.

Techbridge

Techbridge is a nonprofit organization focused on expanding STEM opportunities for girls between fifth and twelfth grades through afterschool and summer programs (Martin, 2014). During these programs, girls create STEM-related projects (e.g., computer-animation, designing prosthetic hands) that have applications in the real world. While many Techbridge afterschool

programs take place on school grounds, the organization sells curriculum for afterschool programs to be implemented in other settings. Afterschool programs collaborate with science-rich institutions to provide experiences for students outside of school grounds. This program provides participants with active learning experiences, which appear consistent with the Maker Movement and problem-based learning initiatives. Program units are designed around each of the STEM fields and include career exploration. Program evaluation results indicate that girls who have been involved in Techbridge programming are two times more likely to pursue a STEM degree in college than the national average, have higher rates of graduation and enrollment in AP calculus courses, and graduate with higher GPAs compared to their peers. In 2012-2013, 81% of girls in this program reported they could see themselves pursuing careers in technology, science, or engineering (Martin, 2014). These outcomes align with the goals of informal STEM education (i.e., interest, capacity, value).

Project Exploration

Project Exploration is a science education nonprofit that promotes engagement in STEM for underrepresented populations (e.g., girls, ethnic minorities) in Chicago public schools. Students served by this program are primarily African American and Hispanic, and more than 50% are girls (Lyons et al., 2012). Through a variety of programs, Project Exploration connects students to scientists and STEM experiences in an informal education setting. This program strives to engage and keep students interested in science while equipping them with the skills and experiences they need to pursue science. The core design elements and practices of this program include equity, relationships, students being at the center, access to experts, and meaningful work (Lyons et al., 2012). Other Project Exploration programs incorporate STEM-related contests, collaborate with institutions of informal science learning and science professionals, and utilize summer camps to encourage STEM participation (Project Exploration, 2006). Project Exploration activities occur in a variety of settings, including on school grounds and in science-rich institutions. Furthermore, Project Exploration holds events at varying community locations such as cultural centers. Programs in Project Exploration utilize active learning approaches consistent with the Maker Movement and problem-based learning. A 2006 evaluation of Project Exploration found that students participating in their programming were 10 times more likely to graduate from high school and major in science compared to similar students from the Chicago public school system (Project Exploration, 2006). Further, Project Exploration participants were significantly more likely to attend college and graduate with STEM degrees compared to their peers (Lyons et al., 2012). These results align with the informal STEM education goals of interest, capacity, and value.

Chicago City of Learning

Chicago City of Learning (CCOL) is a nonprofit organization that is focused on providing interactive learning projects for youth. One unique aspect of this program is that children can earn digital badges via an online platform for various learning projects that they complete, much like the badges that Girl or Boy Scouts sew onto their vests. Indeed, CCOL provides youth with credit for their participation with each subject (Semmel, 2014). The badges can be shared with others, perhaps most importantly with future employers (Chicago City of Learning, 2014). CCOL has partnered with over 100 organizations where children get hands-on learning experiences (Chicago City of Learning, n.d.). Some examples of topics or projects that can earn badges include video editing, spoken word, engineering, architecture, performance, photography, and urban agriculture (Chicago City of Learning, 2014). In addition to a wide variety of subjects, participants in this program have opportunities to learn from various organizations such as Chicago Public Library, Chicago Park District, the Art Institute of Chicago, the Chicago Architecture Foundation, and many other informal education institutions (Chicago City of Learning, n.d.). These connections can be a great networking tools for the young people in this program. While CCOL provides opportunities for youth to engage in STEM across a number of informal education institutions, additional research is necessary to evaluate the effectiveness of this program.

Promising Practices for Informal STEM Education

Informal education is supported in the literature as an avenue through which students can increase interest, confidence, and skills in STEM subjects (Afterschool Alliance, 2011). STEM education in informal settings encourages relationship building between students and adults, is designed for equity and access, and emphasizes the importance of improved research and evaluation to be more effective. By utilizing the informal education theoretical frameworks and approaches in program design and development, institutions and programs are more likely to achieve the informal STEM education goals of interest, capacity, and values among all students.

In regards to the social aspects of learning, research supports the development of students' relationships with peers and adults in informal education programming (Lauver & Little, 2005; National Research Council and Institute of Medicine, 2002). For example, in 21 qualitative student interviews, the students expressed the importance of their relationships with the staff in the informal education program more than characteristics of the program itself (Strobel, Kirschner, O'Donoghue, & McLaughlin, 2008). This indicates that relationship building is an important component of informal education programming. Supporting this finding, the National Research Council and Institute of Medicine (2002) recommends that for afterschool programs to be effective, they should include opportunities for youth to:

- Experience supportive relationships and receive emotional and moral support;
- Feel a sense of belonging;
- Be exposed to positive morals, values, and positive social norms;
- Be effective, to do things that make a real difference, and play an active role in the program; and
- Develop academic and social skills, including learning how to form close social relationships with peers that support and reinforce healthy behaviors, as well as acquire the skills necessary for school success and a successful transition into adulthood.

Complimenting these recommendations, Lyons and colleagues (2012) emphasize how successful afterschool STEM programs need to consist of the following complementary learning strands: 1) discover, 2) explore, and 3) pursue. With the discover strand, students are introduced to a broad range of science topics, practice the basic principles of science and scientific inquiry, engage in activities that build their confidence, and develop long-term relationships with other students, staff, parents, teachers, and scientists. With the explore strand, programs focus on discrete disciplines and inquiry-based methods, critical thinking, collaboration, and public speaking. In addition, investigative approaches are emphasized, and students are empowered to articulate their interests and develop personal science identities. Lastly, the pursue strand focuses on how students are equipped with skills and experience to engage in science in higher education and the workforce; students are provided opportunities for in-depth investigations; the program builds advanced scientific proficiency, leadership and how decision making skills are nurtured and; students develop personal relationships with scientists.

Taken together, this framework provides the components of a promising informal STEM education program (Lyons et al., 2012). Ultimately, youth in informal STEM education programs need to connect with the program, the people, and each other to form a supportive community that promotes STEM learning. Many programs also recognize a need to support the informal educators that implement the programs themselves (Paulsen, 2013). For instance, Paulsen (2013) suggests that support for practitioners should be a component of developing, designing, and implementing informal education programs. In the context of evaluation, Bell and colleagues (2009) recommend utilizing the three strand framework (presented above) to identify ways in which students can learn in informal contexts.

The Institute of Museum and Library Services (2007) also recommends the following practices to promote program sustainability for informal education programs:

1. Building community awareness of project impacts;
2. Partnering with relevant stakeholders (e.g., community organizations, groups, businesses)
3. Diversifying funding streams as programs evolve; and
4. Retaining quality staff and leadership.

These recommendations speak to the importance of informal education programs and why they should build awareness around their program, connect with their stakeholders, diversify their funding, and identify and retain quality staff.

The duration and timing of afterschool STEM programs is an important consideration as well. Informal educational experiences can have a broad range in their duration and timing—from visiting a museum for an hour to engaging in afterschool programming every school day in high school. This fidelity with which students experience these STEM programs and activities varies greatly. Research results are mixed regarding the importance of duration for informal STEM education outcomes. For example, Lauer and associates (2003) found that timeframes (i.e., summer school or after school) for afterschool programs did not influence the effectiveness of the programs for low-achieving students. However, Strobel and colleagues (2008) argued that the frequency and length of an afterschool program influenced STEM outcomes. Further research into best practices for duration of informal education programs is needed.

Another important consideration is when to engage K-12 students in the STEM pipeline. A number of recent studies (Dabney, Chakravery, & Tai, 2013; Gándara, 2006; Maltese et al., 2014; Maltese & Tai, 2011; Tai, Liu, Maltese, & Fan, 2006; VanLeuvan, 2004) have examined when K-12 students are most likely to engage in or disengage from the STEM pipeline. Overall, this research suggests that students need to engage in STEM education and programming during elementary and middle school. These studies suggest that STEM interest and aspirations are formed during this time period. For example, in the context of positive attitudes toward science, a significant decline in attitudes between ages 10 and 14 was found (Archer et al., 2010). Furthermore, Tai, Liu, Maltese, and Fan (2006) argue that early life experiences during elementary school are critical in a student's future career decisions and should not be overlooked.

Longitudinal studies (Dabney et al., 2013; Maltese & Tai, 2011; Tai et al., 2006) provide further support for the importance of early childhood and elementary school experiences in joining the STEM pipeline. For instance, Maltese and Tai (2011) investigated when physics and chemistry graduate students (N = 116) first became interested in science. The majority of participants (65%) shared that their interest in science began prior to middle school. A similar trend was

observed by Dabney and colleagues (2013) in that 41% of physics and chemistry graduate students became interested in STEM during elementary school. Tai and colleagues (2006) conducted a study to examine when individuals decided to pursue degrees or careers in STEM. These researchers found that eighth-grade students who expressed that they were interested in pursuing science careers were two to three times more likely to complete a degree in STEM compared to students who did not have this interest. Taken together, these findings suggest that the majority of students decide to pursue STEM degrees and careers before entering high school (Maltese & Tai, 2011). Specifically, for underrepresented groups, research demonstrates that encouraging interest in STEM needs to occur early in a child's life while their interests are still being formed (Gándara, 2006).

Some studies (e.g., Maltese & Tai, 2011; Sadler, Sonnert, Hazari, & Tai, 2012) indicate that students confirm their decision to pursue STEM careers in high school. For example, findings from a longitudinal study suggest that students who developed an interest in high school in pursuing a STEM major in college were three times more likely to earn a STEM degree than those who planned to complete a different major (Maltese & Tai, 2011). Another study found that males' interest in STEM majors during high school remained consistent throughout high school—39.5% to 37.5%; whereas, females' interest in STEM majors during high school declined from 15.7% to 12.7% (Sadler et al., 2012). These findings suggest that many students know what careers they will pursue by high school, but girls may be especially vulnerable to disengaging from the STEM pipeline.

Overall, these findings suggest that K-12 students need to develop an interest in STEM early during their education. In addition, this interest needs to be nurtured and confirmed during students' high school years. In fact, Maltese, Melki, and Wiebke (2014) found that college students (N = 7,970) who reported that they became interested in STEM during middle school, high school, or their first or second year of college were more likely to pursue a STEM major compared to those who became interested prior to kindergarten. Therefore, informal STEM education programs may be more effective when they are implemented earlier. However, more research is needed regarding optimal settings for providing informal STEM education and programming.

Public Libraries—A Promising Direction for STEM Equity and Access

One setting gaining popularity as an opportune location for informal STEM education is the public library. As a long-standing location for informal education, public libraries are beginning to utilize their existing resources (e.g., Internet access, computers, knowledgeable and friendly staff) as a foundation upon which to expand STEM education. Indeed, a number of national organizations have already begun to support informal STEM education in public libraries,

including the Institute of Museum and Library Services, the American Library Association, the Young Adult Library Services Association, the Association of Rural and Small Libraries, and the Association for Library Service to Children. These organizations engage in research, provide resources, and support the library community in STEM through conferences and blogs (Young Adults Library Services Association, 2011). Through this widespread support, it is evident that public libraries can provide a viable solution to address the K-12 STEM pipeline issues of equity and access in our nation.

Public libraries provide a place and a space for people and information to come together (Prentice, 2011). These institutions support life-long learning that can enhance the personal development of their patrons by providing free and easy-to-access information, resources, and a safe and welcoming environment (Durrance & Fisher, 2003). There are well over 17,000 public libraries nationwide (Swan et al., 2013b). This means that public libraries may be easier to access than other informal education settings (Dusenbery & Curtis, 2012). According to the Association of Science -Technology Centers and Urban Libraries Council (2014), public libraries and museums are known for providing people of all ages a place to pursue their interests, have meaningful experiences, and gain expertise. Public libraries are places that allow lifelong, life-wide, and life-deep learning experiences (Bell et al., 2009). According to Prentice (2011), the public library as a place represents three components—the vision of what the community believes the library is and should be, a virtual repository of information and connection, and a physical space.

Public libraries also serve a vital role in their communities. Citizens can turn to public libraries to address the myriad of situations they experience in their lives, from learning new job skills to finding educational materials for their children (Pettigrew, Durrance, & Vakkari, 1999). Dusenbery and Curtis (2012) describes how, compared to other forms of informal education such as museums, zoos, and aquariums, public libraries offer services to families at no cost and are closer to their homes. Public libraries also champion the rights of individuals by providing equitable and easy access to information and resources (Pettigrew et al., 1999). Further, public libraries provide a place for low-income families to access resources and information and thus help address equity educational disparities (Spielberg & Whalen, 2002). Clearly, public libraries support equity and access in our nation. Furthermore, public libraries may represent the only public institution in our country that serves the whole community and has the capacity to address equity and educational disparities.

The Pew Research Center (2013) conducted a survey of 6,224 Americans, in English and Spanish, who were 16 and older to understand how people utilized public library services in the U.S. Findings from this study indicated that Americans view public libraries as a place that

provides them with valuable services and access to materials and resources that help to improve their literacy and quality of life. Participants reported that public libraries were doing a good job of embracing new technology. When participants were asked to rate how important specific library services were to them and their families, the following trends were rated somewhat important to very important:

- Books and media (80%);
- Librarian assistance (76%);
- Having a quiet, safe space (75%);
- Research resources (72%); and
- Programs for youth (69%).

It is clear from this research that Americans view the public library favorably, as a place that provides them with valuable resources, information, safety, research tools, and programming for youth. It should also be noted that minority groups (e.g., women, African Americans, Hispanics, low SES populations, less educated adults) were more likely to rate these library services as very important (Pew Research Center, 2013).

Another similar study that was conducted by the American Library Association (2012) found that high percentages of families and underrepresented minority groups utilize public libraries. Indeed, public libraries are one of the only free access spaces where immigrant populations can: 1) find information about schools, jobs, and English classes, 2) feel less isolated, 3) connect with their new culture, 4) borrow books, tapes, and other materials for children, and 5) learn how to use a computer and have access to this resource (Prentice, 2011). Another benefit of public libraries is that they help patrons during times of change. For example, the Pew Research Center (2014a) found that people are more likely to utilize and engage with libraries when they experience different life stages (e.g., being a student, retirement) and during special circumstances (e.g., having a child, seeking a job). The public library connects all kinds of people to information that can benefit and support their lives. Librarians understand that public libraries must adapt with the changing times to serve their patrons in the 21st century.

Public Libraries During the 21st Century

The Institute of Museum and Library Services (2009) suggests that public libraries need to take proactive steps to strategically position themselves for the future given that the economy is changing, there are new trends in learning, and new expectations from patrons. In 2009, librarians came together at a conference called the "In the Foothills: A Not-Quite-Summit on the Future of Libraries" to discuss the future of librarians in the 21st century. These discussions produced a document called *The Darien Statements* on the public libraries and librarians that

captured what librarians thought the role of public libraries and librarians would be for the future. The following excerpt, taken from Prentice (2011, p. 9), summarizes how librarians view their role in the 21st century:

The purpose of the library is to preserve the integrity of civilization, that it has a moral obligation to adhere to its purpose despite social, economic, environmental or political influence, and that purpose will never change. The library is infinite in its capacity to contain, connect and disseminate knowledge; librarians are human and ephemeral, therefore we must work together to ensure the Library's permanence. Individual libraries serve the mission of their parent institution or governing body, but the purpose of the library overrides that mission when the two come into conflict. Why we do things will not change, but how we do them will. A clear understanding of the Library's purpose, its role, and the role of librarians is essential to the preservation of the library.

In this statement, it is clear that librarians understand that their role is one of serving and providing information and knowledge to patrons from all walks of life. The library and librarian must evolve with the times, especially to sustain their role in their respective communities.

Pastore (2009) provides practitioners a valuable discussion guide regarding the future of museums and libraries. In this guide, the following nine discussion themes were explored:

1. Changing definitions and roles of museums and libraries;
2. Shifts in power and authority;
3. Libraries as the "third place";
4. Technology and policy development;
5. 21st-century learning and information use;
6. New models and structure for collaboration;
7. Planning for a sustainable future;
8. Metrics for evaluation service and impact; and
9. The 21st-century museum and library workforce.

These themes speak to the ways in which public libraries and museums are changing and need to change to better address the needs of their users. As Pastore (2009) stated, this discussion guide was written as a call to museums and libraries to be proactive in how they face the inherent challenges and opportunities of the 21st century. These changes in the access and use of information along with the preservation of knowledge are supported by shifts in technology. Prentice (2011) notes that while technology has not changed the purpose of public libraries, it has changed how this institution brings people and information together. Therefore, as

librarians prepare for the 21st century, they must consider how they use technology as both a tool to manage libraries, but also as a way to provide their services.

The Aspen Institute (2014) describes public libraries as being at the center of the digital age. These researchers discuss how public libraries can help individuals and communities adapt to changing times by serving as community connectors. The fact that there are almost 9,000 public library systems that include 17,000 library branches along with outlets nationwide demonstrates that an infrastructure to produce long-term success in STEM programming already exists. Duff (2012) encourages librarians to embrace the opportunity to support STEM learning and demonstrate how essential public libraries still are during the digital age. Moreover, as there is a national emphasis on STEM learning in both formal and informal education, there is a great need for high quality digital instruction (Mardis, 2014). The Pew Research Center (2014a) acknowledges that public libraries are trying to respond to the new technologies of the 21st century while preserving older traditional knowledge dissemination strategies. As a result, public libraries have added new technologies and formats, expanded gathering places, and offered additional events and services.

To address the issues of the 21st century and build momentum, the Institute of Museum and Library Services (2009) proposes six steps for libraries and museums to follow:

1. Engage with community;
2. Establish the vision;
3. Assess current status;
4. Implement a prioritized plan;
5. Focus on comprehensive alignment; and
6. Track and communicate progress.

These steps speak to the importance of public libraries embracing and adapting to the changing times in order to better serve their patrons. In addition, such steps emphasize the importance of public libraries forming strategic partnerships and developing plans for action.

The Aspen Institute (2014) suggests that in order for public libraries to fulfill their new roles in the 21st century, they need support from leaders, policymakers, and community stakeholders. This kind of support will enable public libraries to re-envision their new roles and better provide resources to the communities they serve. Prentice (2011) makes a number of recommendations as librarians move into the 21st century including:

1. Creating a space that is transparent, open, and kind among libraries and users;

2. Improving connections between the library and its users;
3. Embracing change;
4. Helping users learn and acquire knowledge; and
5. Trusting the users.

The fact that public libraries and librarians are ready and willing to embrace the needs of the 21st century makes them an ideal location for informal education and programming for underrepresented youth.

Public Libraries as Informal Education Institutions

Children and young adults visit public libraries because these institutions provide them a place to access technology (e.g., computers), media (e.g., books, magazines), and resources for homework, and provides them a place to socialize with their friends through community events (Fields & Rafferty, 2012). Indeed, public libraries are well-suited to offer afterschool programming and other forms of informal education to youth. For example, the Institute of Museum and Library Services (2007) suggests that libraries and museums provide youth with "extra learning opportunities" outside of formal education through complementary leadership, rich resources, and effective programs. Spencer and Huss (2013) also describe public libraries as an ideal environment that can supplement formal education and provide a relaxed place for youth to discover, dream, create, and invent. Public libraries also provide a safe place for students to learn and grow.

Public libraries are well connected to other agencies that serve youth, providing resources such as dedicated and knowledgeable staff, information, opportunities for personalized, hands-on learning, and strategies to make learning fun and rewarding (Institute of Museum and Library Services, 2007). There are many benefits that libraries can provide their young adult patrons. For example, public libraries have ongoing relationships with schools, home school groups, and community organizations that provide industry knowledge, networks, and funding. These institutions also have the capacity to advertise their programs through their newsletters, library websites, and intercom announcements, which can enhance the effectiveness of library programs (Fields & Rafferty, 2012). The fact that public libraries are so responsive to the needs of their patrons makes them ideal for providing STEM learning, which is also ever-changing (Baek, 2013a). Public libraries also have high repeat visitation rates compared to other informal education institutions (Fitzhugh, Coulon, & Elsworth, 2013).

Public Libraries and STEM Programming

Public libraries hold great promise for promoting STEM equity and access for K-12 students (Dusenbery, 2014a). The fact that there are so many public libraries and branches in the nation

demonstrate that these institutions can provide an infrastructure that serves the needs of students likely to disengage from the STEM pipeline. Public libraries also provide a “third space,” or a space beyond the formal classroom and home, that unites schools and communities around STEM education (Baek, 2013a.). Koester (2014) argues that these institutions already have the resources, customer interest, and library goals surrounding youth programs and services to make these programs successful. However, programming will differ from one library to another as these institutions differ in terms of size, shape, location, staffing, funding, and support (Koester, 2014).

Over the last few years, there has been a movement toward offering STEM education and programming in public libraries. For example, some libraries have begun to include STEM activities in their existing youth programming (Dusenbery, 2014a; Dusenbery, 2014b; Dusenbery & Curtis, 2012). Public libraries have also developed innovative programs and activities to engage K-12 youth in STEM (Roberson, 2015). It is not surprising then that a number of researchers (e.g., Baek, 2013a; Falk & Dierking, 2010; Koester, 2014) have argued that public libraries can engage youth in STEM learning.

Dusenbery (2014a) suggests that public libraries understand the importance of supporting academic achievement and as a result, they are receptive to innovative and interactive STEM programming to engage their youth patrons. Students can explore, make mistakes, and participate in hands-on activities of their own volition as public libraries provide a space and place for youth to learn STEM free of judgment and grade pressure (Young Adults Library Services Association, 2011). Unfortunately, public libraries have been slower to adopt STEM education and programming compared to school libraries⁴ (Hopwood, 2012). As a result, the evaluation of STEM programs in public libraries⁵ has been sparse.

⁴ School libraries have provided STEM education opportunities to K-12 students. These programs have been associated with positive outcomes for students (Mardis, 2014; Subramaniam et al., 2013). Duff (2012) argues that school librarians can facilitate STEM learning by providing students with guided access to STEM books, magazines, websites, databases, experts and programs. Unfortunately, teachers and school librarians may not frequently collaborate with each other to support STEM learning in formal education (Mardis, 2014).

⁵ While public libraries have been recognized for their ability to measure inputs (e.g., financial, staffing, and material resources) and more recently outputs (e.g., transactions, use and usability of materials), efforts to quantify excellence and impact have been limited (Durrance & Fisher, 2003; Kyrillidou, 2002). In fact, for several decades, research has focused on standards and inputs, only recently has the focus
(footnote continued)

Amidst budget cuts in recent years, public libraries have continued to demonstrate their value by partnering with schools and other community partners (e.g., nonprofits, universities) to serve their patrons (Roberson, 2015; Young Adults Library Services Association, 2011). Hopwood (2012) argues that public libraries that adopt STEM are more likely to gain support through joining education initiatives and building their community partnerships. As budget cuts in national, state, and local funding have negatively impacted the quality of education in schools, public libraries can offer a viable option to supplement STEM education. Hopwood (2012) recommends public libraries integrate STEM programming into their existing programs to address budget constraints. Thus, while STEM programming in public libraries is still a relatively new movement, it is evident that adopting and integrating STEM into the public library landscape provides many benefits.

Examples of Promising STEM Programs in Public Libraries

The following section describes four promising STEM programs that are currently being implemented in public libraries. These programs provide informal STEM education activities to youth by providing interactive, collaborative, hands-on activities. Each of these programs has also begun to evaluate youth impact and outcomes.

STAR_Net Libraries

The STAR Library Education Network (STAR_Net) is a national informal education program developing STEM-related exhibitions, activities and training, and outreach programs (<http://www.starnetlibraries.org/starnet.html>) for library settings (Dusenbery, 2014b). STAR stands for Science-Technology Activities and Resources. By providing resources and activities for libraries, in addition to professional development and training for librarians, STAR_Net builds capacity for public libraries to provide informal STEM education. Summative evaluation of STAR_Net programs (Evaluation and Research Associates, 2013) indicated that programs had positive impacts on library communities that hosted exhibit programs, including:

- An increase in libraries hosting STEM-related programming or activities in the six months following the STAR_Net programs; and

shifted to outputs and outcomes (Durrance & Fisher, 2003). What this means is that measuring the impact of library programs and STEM programs and activities is still emerging. For example, Kyrillidou (2002) discussed how little is currently known regarding the relationship between inputs, outputs, quality, and outcomes. As a result, effective evaluation of library programs, including STEM, are still evolving.

- An increase in the interest, knowledge, and engagement of library patrons in the STEM exhibit topics.

These results suggest potential for long-term impact for initiatives of STAR_Net programming.

YOUmedia Learning Lab Network

Learning Labs are informal education spaces in libraries and museums that provide STEM-related experiences for middle school and high school students through digital media and technology. These programs are based on principles of Connected Learning and initial evaluations indicate help students:

- Gain exposure to various interests;
- Develop expertise in areas of interest; and
- Connect interests to academic and career paths.

Though each Learning Lab is unique to its setting, all aim to support students in “hanging out,” “messaging around,” and “geeking out” in their areas of interest with peers and supportive mentors (Association of Science-Technology Centers and Urban Libraries Council, 2014). YOUmedia builds learning ecosystems that engage teens, provide mentors, and offer a physical space for the program to be successful (Association of Science-Technology Centers and Urban Libraries Council, 2014).

Learn, Explore, And Play (LEAP)

LEAP: Science is Fun! is a library program focused on connecting STEM subjects to everyday experiences for students ages 8 to 13. Utilizing collaboration with public school teachers and STEM professionals, LEAP: Science is Fun! created STEM kits that students could check out of the library and take home. This program has incorporated inquiry-based learning in monthly library programming with student free choice in selection of which kits to take home. Evaluation of the LEAP: Science is Fun! demonstrated that students who engaged with the program had: 1) increased interest in science, 2) considered a career in science, 3) increased attentiveness to everyday science, and 4) increased interest in reading about science (Bevan et al., 2010).

Explore Library Program

Explore! is a program that was developed by the Lunar and Planetary Institute (<http://www.lpi.usra.edu/education/explore/>) with a 16-year history. This program offers over 100 space science activities and supportive resources for children and pre-teens that are free, hands-on, research-based, and engaging (LaConte et al., 2015). Various types of informal

education settings such as libraries, camps, museums, planetariums, and clubs can use the flexible and easy to implement activities provided by this program. This program is designed to provide library professionals with materials, content knowledge, skills, and confidence to facilitate STEM training to youth (LaConte et al., 2015). To date, more than 900 librarians and educators across 35 states have been trained how to implement *Explore!* Initial findings suggest that trainees experienced significantly higher levels of Earth and space science content knowledge, confidence, and higher intention to use the activities after training (Buxner & Jaksha, 2014). In a follow-up survey (N = 186), 86% of trainees reported actively using *Explore!* Activities and 60% reported implementing these activities on a regular basis (Buxner & Jaksha, 2014). Impact on *Explore!* trainees is evident. However, more research is needed regarding youth outcomes.

Promising Practices for STEM Programming in Public Libraries

Based on the studies reviewed in this report, there are some overarching promising practices that emerged from the research. These promising practices highlight different components of effective programs in public libraries. However, less is known regarding best and promising practices specific to STEM programming in public libraries. Thus, this section synthesizes and integrates findings and recommendations across various settings such as school libraries, general informal education programs, and STEM education and programming in public libraries. Across contexts, STEM programs appear to be more successful when they are supported by librarians, provide opportunities for youth to actively engage in and shape the activities, involve partnerships, and include professional development for library staff.

STEM Programs in School Libraries

In the context of school libraries that provide STEM programming, several best practices were identified. First, collaboration between school libraries and teachers is critical. Unfortunately, Rawson (2014) notes that school librarians and teachers rarely collaborate. To strengthen collaboration, Montiel-Overall (2005) provide a framework that suggests that collaboration between librarians and teachers should involve shared thinking, problem-solving, and creation of integrated instruction. Montiel-Overall (2005) emphasize how school librarians and teachers need to unite around shared vision and objectives to best serve students. Additionally, Rawson (2014) describes four opportunities that can promote collaboration between these groups: 1) traditional literacy instruction, 2) information literacy instruction, 3) classroom technology integration, and 4) connecting science to student's daily lives. Taken together, librarians and teachers can improve collaboration efforts by simply working together to promote STEM learning in their students.

Second, the literature suggests that school libraries need to develop better strategies to connect students with STEM education and resources (Subramaniam et al., 2014). Providing STEM materials and tools can help students engage in the STEM pipeline, but librarians need to directly promote and facilitate STEM education and programming to make it effective. It may also be useful to connect learning to students' interests and experiences with STEM, embrace diversity to promote science learning, and encourage science learning as a social enterprise (Subramaniam et al., 2015). Supporting this perspective, Duff (2012) provides 10 steps to create a cutting-edge STEM school library:

- Highlight existing STEM resources—maximize the visibility of STEM materials;
- Request STEM resource suggestions—ask stakeholders (e.g., students, staff) for STEM resource recommendations;
- Emphasize STEM in book orders—work with vendors to identify and purchase STEM learning materials;
- Keep up with trends in technology—create a stellar library website that links to online STEM resources such as the California Science Center website or (www.californiasciencecenter.org)NASA's Jet Propulsion Laboratory website (www.jpl.nasa.gov);
- Provide STEM-themed library orientations—bring science classes to the library to learn how to access STEM materials;
- Present STEM book talks—select fiction and nonfiction STEM materials to present in science and mathematics classes;
- Communicate STEM resource reminders on a regular basis—disseminate information about programming via newsletters, website posts, announcements, and bulletin boards;
- Invite STEM guest speakers—reach out to STEM authors, public librarians, scientists, mathematicians, and other similar individuals to speak about STEM topics;
- Encourage parent/caregiver and community STEM involvement— communicate with parents about transforming your library into a STEM library and share how they can be involved; and
- Publish library data for all stakeholders—communicate to stakeholders about the data your library is tracking to build support.

While these suggestions focus on school libraries, they can readily be applied to public libraries to strengthen STEM programming and activities. Furthermore, these recommendations offer students a variety of ways to engage in STEM at their school libraries. It is also interesting to note that school and libraries can work together to develop and nurture STEM education and programming that targets K-12 students. By encouraging schools and public libraries to work

together, this approach promotes STEM education and programming through formal and informal learning environments.

Youth Programs in Public Libraries

The Institute for Museums and Libraries (2007) suggests that the most effective youth programs in public libraries possess the following attributes:

- Long-term, trusting, supporting relationships between youth and adults;
- Staff who are trained or receiving training to work with youth of a specific age;
- Partnerships with community-based organizations and cultural institutions;
- Programs that address gaps in what existing youth programs provide;
- Incentives, recognition, or employment opportunities that highlight youth accomplishments;
- Include the youth in the development, design, and decision-making to support programs;
- Provide work or service that is meaningful to youth;
- Connect families and communities; and
- Regularly apply evaluation findings and apply lessons learned to strengthen program efforts.

These attributes emphasize the importance of trusting adult relationships, trained staff, forming strategic partnerships, including and engaging youth in program design, providing meaningful activities, involving families and communities, and evaluating outcomes.

STEM Programs in Public Libraries

In the context of STEM programs in public libraries, promising practices are limited. However, the following examples demonstrate the ways in which STEM programming practices and ideas are being implemented—in many cases with success—in public libraries. Programs that are built to engage youth, developed with their feedback, involve caring mentors, offer a good physical location, and provide professional development for librarians appear to be more effective. For example, the YOUmedia library program at the Chicago Public Library found that teen engagement, mentors, and physical space were the characteristics that made the program successful (Association of Science-Technology Centers and Urban Libraries Council, 2014). In other words, encouraging teens to be involved in planning and designing the program, promoting relationships between mentors and teens, and providing learning labs that were varied, engaging, and were developed with input from youth made the program more successful. In addition, building on teens' existing engagement with media, this program utilizes digital media to provide engaging learning opportunities for young adults (Sebring et al., 2013).

Prentice (2011) recommends that librarians need to understand the interests and concerns of the youth they serve. The Institute of Museum and Library Sciences (2014a) discusses how library programs can help STEM learners of all age groups by:

- Providing people of all ages and backgrounds with mentor-led learning opportunities that spark curiosity and build interest in STEM subjects;
- Providing adults, families, teens, and children with new technology and equipment, including state-of-the-art digital media production tools;
- Introducing learners who are underrepresented in the STEM workforce to important STEM concepts and skills, including authentic scientific practices;
- Providing learning spaces that feature youth-centered approaches to enhancing technical knowledge, strengthening independent learning skills, and building a foundation for the pursuit of higher education STEM opportunities and jobs; and
- Positively impacting academic achievement in science.

Hopwood (2012) makes a number of recommendations to promote STEM in public libraries including: hosting open-book trivia contests with STEM content, creating STEM displays, offering Legos activities, providing family science nights, offering STEM-related storytimes, providing video gaming technology, hosting cooking programs, providing sports activities that integrate statistics, and showcasing technology so that patrons can take a closer look at tablets, e-readers, and cameras. Jaeger (2013) offers some additional ideas geared toward promoting mathematics like holding competitions for kids to find real-world mathematics applications, highlighting ratios by posting circulation statistics, and tracking genre checkouts and displaying this information for students to see. Additionally, Anderton (2012) makes the following recommendations to easily integrate STEM into public libraries:

1. Promote your STEM program to educators and parents;
2. Create STEM booklists and include STEM-related items in general booklists;
3. Advertise your STEM resources on your blog or via other social media tools;
4. Apply for a grant;
5. Involve other departments, employees, and administrators in your organization;
6. Involve others in your community;
7. Host an in-house STEM program;
8. Build slowly; and
9. Ask teens to help you.

More recently, as part of the STAR_Net project, data were collected from 455 library professionals to examine: 1) what kinds of STEM program are currently taking place in public

libraries, 2) what obstacles prevent libraries from implementing STEM, and 3) what kinds of professional development opportunities would help librarians (Hakala, MacCarthy, Dewaele, & Wells, 2016). Results from this study indicated that many public libraries are already offering STEM programming. Specifically, 30% of library professionals reported offering STEM programming “occasionally” (i.e., at least 2 or more times a year), 29% provided STEM programming “frequently” (i.e., more than once a month), 26% offered STEM programming “monthly”, 8% reported they offered STEM programming during the summer only, and 7% reported trying STEM programming once (Hakala et al., 2016). In fact, 97% of library professionals shared they were interested in offering more STEM programming opportunities to their patrons. As momentum for STEM programming in public libraries grows, Hakala and colleagues (2016) make the following recommendations to support future STEM efforts:

1. Create and distribute how-to resources and pre-packaged programming to library professionals that can be easily disseminated;
2. Develop concrete materials such as activities, techniques, or games that demonstrate how to teach STEM concepts, especially math;
3. Incorporate STEM concepts into existing programs that already serve girls and forge partnerships with organizations such as Girl or Boy Scouts; and
4. Provide professional development in-person and online to library professionals who already are invested in STEM knowledge and skills.

The above suggestions represent the richness of STEM ideas being proposed and implemented across public libraries in the United States. Indeed, there are myriad innovative ideas that can strengthen STEM programming and capacity in public libraries. The Center for Advancement of Informal Science Education (Bevan et al., 2010) also emphasizes the importance of formal-informal collaboration to promote STEM learning, describing how these agencies share the goal of making science learning more accessible and engaging for youth.

The professional development of public librarians was clearly cited as an important component of best and promising practices in STEM programming (Hakala et al., 2016). Baek (2013b) discussed how many STEM librarians entered into this role accidentally and, as a result, may have concerns about their abilities and competency. Hakala and colleagues (2016) also found that barriers such as a lack of time, staff, resources, support for new technology, and confidence in teaching STEM materials may prevent or limit library professionals’ ability to implement or increase STEM programming.

One approach to address these perceived barriers is that the Institute of Museum and Library Services (2009) advocates for libraries to develop their institutional capacities to support 21st

century skills. Hopwood (2012) also describes how people without science backgrounds may be able to better relate to youth who may also lack this content knowledge, suggesting that passion and a willingness to learn are what matters most. By leveraging existing librarian skills, knowledge about literacy practices, and providing professional development opportunities, librarians will feel more confident in this new role (Baek, 2013b). Bell and associates (2009) recommend that front-line educators (i.e., librarians) need to develop cultural competence and learn about the groups they want to serve to be more effective. More research is needed regarding strategies to improve librarian self-efficacy and motivation to facilitate STEM activities and programming.

Another important consideration is how to sustain STEM programming in public libraries. The Aspen Institute (2014), in re-imagining public libraries, offers four strategies to help public libraries sustain their sustainability:

1. Align library services in support of community goals;
2. Provide access to content in all formats;
3. Ensure the long-term sustainability of public libraries; and
4. Cultivate leadership.

These strategies suggest that public libraries integrate this programming into their existing infrastructure and present the importance of sustaining public libraries more generally. Fields Rafferty (2012) made the following recommendations surrounding program-specific sustainability:

1. Provide clear and ongoing communication between partners;
2. Provide a replicable program based on quality research-based curriculum geared toward youth;
3. Provide ongoing training to program staff and leaders; and
4. Diversify funding streams.

All of these recommendations are built on strong collaboration with partners. Fields Rafferty (2012) also highlighted some lessons learned from implementing an informal STEM education program, such as the importance of adopting weekly programming rather than monthly programming, making sure that content lasts for 90 minutes or less so teens don't lose focus, making sure that outreach (e.g., emails, reminder calls, onsite signage) is an ongoing effort, and staying abreast of the growing and changing needs and interests of youth. Although these recommendations are insightful at the program level, more research is also needed regarding

the best and most promising practices for public libraries seeking to integrate STEM education and programming into their institutions.

Recommendations for Public Libraries

Based on the review of the literature, which examined informal education, informal STEM education and programming, public libraries, and STEM programming in public libraries, a number of recommendations are offered in this report. These recommendations synthesize information from various sources to provide best and promising recommendations for STEM programming in public libraries to date. While evaluation and assessment in this context is limited, it is believed that the recommendations provided below will enable STEM programming in public libraries to be more effective for historically underrepresented K-12 populations. These complementary recommendations are intended to help public libraries develop, integrate, and strengthen STEM programs and activities. The following eight recommendations offer public libraries tools and resources to provide and sustain informal STEM education and programming in their institutions.

1. Collaborate with STEM Stakeholders

As public libraries adopt and improve existing and new STEM programs, it will be important for them to collaborate with STEM stakeholders. Public libraries need to identify STEM professionals, community leaders, community-based organizations, schools, and universities that provide STEM education. These stakeholders can help public libraries develop a bridge between research and practice. Librarians can benefit from the expertise of these stakeholders while public libraries can simultaneously offer a space and friendly staff to support STEM programming efforts. Collaboration between STEM stakeholders includes both formal and informal STEM education institutions. By collaborating with STEM stakeholders, public libraries build their capacity to offer STEM education and programming. STEM stakeholders have the content knowledge, curriculum, and programming tools to support STEM education and programming in public libraries. Additionally, libraries are able to easily integrate these tools into existing public library infrastructures.

2. Form Partnerships with Organizations That Serve Youth

Forming partnerships with organizations that serve youth, especially historically underrepresented youth, can strengthen public libraries' capacity to serve youth and help mitigate the barriers that youth may face. As informal youth education programs and public libraries are often constrained by finances, these intentional partnerships can help support STEM education and programming. Programs that utilize best practices for youth development programs have been found to be more effective. Thus, the positive youth development model, which focuses on long-term trusting, supportive relationships with adults, trained staff,

recognition, ownership in developing STEM activities and programs, meaningful work, connections to families and communities, and evaluation, can be utilized through public libraries to better serve youth. Furthermore, when public libraries identify similar organizations in their area, they can fill gaps in services that are not being offered to youth. When public libraries form strong partnerships with other organizations that serve youth, they build a social network that supports youth from multiple angles.

3. Target Historically Underrepresented K-12 Youth

Since a disproportionate number of youth who disengage from the STEM pipeline are historically underrepresented K-12 students, public libraries should target this population for STEM education and programming. These institutions are well-positioned to help address this education disparity and may be more effective than other informal education settings because they provide a safe, trusted, and welcoming environment. Public libraries are free and located closer to where historically underrepresented K-12 youth live. Historically underrepresented K-12 youth are also most at risk of disengaging from the STEM pipeline; therefore, public libraries can better demonstrate their community impact by serving this population. Providing staff from these communities and employment and service opportunities may also strengthen the impact that public libraries can make in these communities. As the nation deems STEM a national priority, and historically underrepresented K-12 youth have been identified as a priority for STEM education and programming, it can only benefit public libraries to align with STEM initiatives.

4. Make STEM Programs Accessible and Equitable for All Youth

Public libraries already provide a number of services that promote equity and access to adults. Building on Recommendation 3, public libraries can offer their programs and services for free. This is a key factor that differentiates public libraries from other informal education institutions such as museums, zoos, and aquariums. The welcoming atmosphere of public libraries coupled with friendly and knowledgeable staff help make this setting accessible and equitable to all groups of youth. To further improve the reach of informal STEM education programs, public libraries could implement some kind of voucher system to make transportation easier for youth. Public libraries could also reach out to parents and caregivers to further support STEM education and programming. When these parents understand the importance and value of these programs, they will be more likely to enroll their children into these programs. In addition, sharing this knowledge is another way in which public libraries make STEM programs accessible and equitable for all youth.

5. Develop Strong, Lasting, Caring Adult-Youth Relationships

Across all types of formal and informal education and programming, youth need to develop strong, lasting, caring relationships with adults. These adults may be librarians, STEM program

staff, STEM mentors, parents, or volunteers, who provide guidance, support, and mentoring to youth. Having a consistent social network of people that youth can trust as they engage in STEM education and programming in public libraries is critical. The theme of caring adults emerged in the informal education, informal STEM education, and public library literature as a component of effective youth development programs. Some STEM programs could even be implemented through high school and college student volunteers. This collaboration could provide an avenue for STEM programming that can impact more youth and help them maintain interest, capacity, and value in STEM.

6. Provide Training and Professional Development Opportunities to Librarians

As some librarians believe that they lack the skills and confidence to implement STEM programming, it is important to provide these individuals with additional training and professional development opportunities. Librarians can receive training in youth development and programming, along with information about how to facilitate STEM-specific programs and activities. Training librarians and developing leaders creates quality public library staff, which has been identified as a best and promising practice. In addition, the lack of familiarity in STEM subjects may be an asset rather than a deficit as librarians will be better equipped to bridge the content for K-12 students. Librarians simply need to feel empowered to facilitate STEM education and programs, partner with experts, and direct students to STEM resources. All this can be accomplished through proper training and professional development opportunities.

7. Evaluate STEM Programs and Monitor and Track Outcomes

While evaluation and assessment efforts in STEM education and programming in public libraries need further development, public libraries can begin to evaluate and track their outcomes. What is required is a focus on how inputs and outputs contribute both short- and long-term outcomes. In many regards, this is an extension of the data that public libraries already track from other contexts. Moreover, public librarians can work with evaluators and academics who have specialized expertise in this area to supplement their program evaluation capacity. One benefit of evaluating STEM programs and monitoring and tracking outcomes is that public libraries can assess the impact of their STEM programs and determine areas for improvement. Another benefit of tracking outcomes is that public libraries can share their findings and impact with the larger community. This in turn will increase the likelihood that public libraries will continue to receive funding that can support STEM and other public library programs in the future.

8. Share Results with Stakeholders

Finally, as public libraries continue to adopt STEM education and programming, it will be important to share their results with stakeholders. What this means is that in addition to evaluating, tracking, and monitoring outcomes, public libraries need to share information about

their impact with the larger community. Sharing this knowledge will help other public libraries strengthen their STEM programs and initiatives. Communicating with partners and collaborators builds a community that is better able to serve the needs of historically underrepresented K-12 youth. Sharing findings will also improve current evaluation efforts that are already underway. Most importantly, sharing results with stakeholders is a vital step in the sustainability of STEM programming and education in the public library sector. These institutions need to tell their stories and it is fitting that STEM skills (e.g., technology and mathematics) are utilized to achieve this objective.

Next Steps and Future Directions

Engaging students in the STEM pipeline and maintaining their interest in this area is still a relatively new area of research, particularly for public libraries. In fact, Maltese, Melki, and Wiebke (2014) allude to a number of research questions that still need to be addressed on this topic such as:

- Do STEM outcomes (e.g., degree completion, advanced persistence) differ between students based on their initial interest in a STEM career?
- When is interest in STEM first initiated?
- How long is STEM interest maintained?
- Does initial interest in STEM lead to a student's pursuit of a STEM degree or career?
- How is initial interest in STEM maintained?
- What is the role of formal and informal learning experiences in generating and maintaining STEM collectively?

There is also a dearth of research surrounding the optimal timing to engage and maintain students in the STEM pipeline. Moreover, understanding the factors that support and hinder K-12 students' interest, engagement, and aspirations in STEM requires further research. For public libraries, evaluating the effectiveness of STEM activities, services, and programs is clearly needed moving forward.

A new promising direction in STEM education and programming focuses on rural students as an emerging historically underrepresented group. One in five students attends a rural elementary or secondary school (Johnson, Showalter, Klein, & Lester, 2014). Rural students experience many of the same barriers that other historically underrepresented groups face. However, this group has its own unique set of challenges —rural students are situated in remote areas with limited formal education resources and fewer opportunities for informal STEM programs (Burton et al., 2014). This may be part of the reason that future research may need to focus

more on this population, as they may be at greater risk of disengaging from the STEM pipeline. Indeed, to date, little research has examined how STEM outcomes are impacted for rural students (Avery, 2013) and how rural public libraries can best serve these students (Swan, Grimes, & Owens, 2013).

Another promising direction is the STEM ecosystem model. Researchers have begun viewing STEM education as an “ecosystem,” precipitated by huge advancements in technology and greater access to various learning opportunities and materials (Falk et al., 2016). The term ‘ecosystem’ brings to mind a network of organic, interwoven connections all strengthening one another towards a particular goal. Studies have demonstrated that most high-interest and enriching STEM learning occurs outside of the formal education system, within museums, zoos, aquariums, after-school organizations, and even a simple walk through park; these activities and places constitute a child’s STEM ecosystem (Falk, 2015; Falk et al., 2016; Noyce Foundation, 2014).

Many researchers now suggest that influencing the connections in a child’s STEM ecosystem provides the best method to engage and reinforce learning. Semmel (2015) speaks to the importance of a *collective* impact of various organizations, in contrast to individual organizational goals, which will ultimately lead to universal and lasting change for STEM ecosystems. Various organizations together tackling the lack of lasting STEM education will create necessary learning reinforcements for children, and give rise to sustained planning and collaboration on the community level (Noyce Foundation, 2014). Ultimately, an ecosystem flourishes best when all aspects function in unison towards a common goal: in this case, STEM inputs, such as the school system, after-school clubs or activities, social networks, and community resources or organizations, all function together to elicit permanent and lasting learning and skills acquisition within children and adolescents.

This literature review demonstrates that there are a variety of promising programs and activities that support STEM in schools, informal education settings, and public libraries. Momentum for STEM education and programming in public libraries is growing. STEM is now a national priority, especially for historically underrepresented K-12 youth. However, since this is a relatively new movement, there is a need for more evidence-based STEM programs in public library settings. It is critical to reach out to public libraries that are not yet involved in this movement and provide resources to institutions just getting started. It is evident that public libraries can provide an informal education infrastructure to improve the effectiveness of the overall STEM educational initiative in our nation. Encouraging librarians to join the STEM initiative with equity and access guiding implementation efforts will help improve the effectiveness of STEM education and programming in our nation.

There are a number of resources that can help libraries and librarians get started and build their STEM programming. For professional development materials, please refer to STAR-Net libraries resource section (<http://www.starnetlibraries.org/resources/>) and to find STEM related activities please refer to STEM Activity Clearinghouse website (<http://clearinghouse.starnetlibraries.org/index.php>). These resources can provide assistance and ideas to develop, implement, and evaluate STEM education and programs in public libraries.

Conclusions

In conclusion, public libraries offer a viable solution to address the STEM equity and access issues in our nation. These institutions can provide places, platforms, and programs to support historically underrepresented K-12 students' engagement and persistence in the STEM pipeline. This report reviews the literature on equity and access of historically underrepresented K-12 students, informal education, informal STEM education, public libraries, and public libraries with STEM education and programming to produce the following eight key recommendations: 1) collaborate with STEM stakeholders; 2) form partnerships with organizations that serve youth, 3) Target historically underrepresented K-12 students, 4) make STEM programs accessible and equitable for all youth, 5) develop strong, lasting, caring adult youth relationships, 6) provide training and professional development opportunities, 7) evaluate STEM programs and monitor and track outcomes, and 8) share results with stakeholders.

This report is intended for librarians seeking to adopt and strengthen STEM education and programming in public libraries. This report also focuses on current trends and practices in public libraries, especially in the context of STEM education and programming, providing a baseline for what these informal education institutions are currently doing to address this education disparity. The recommendations and resources included in this report provide policymakers, practitioners, researchers, and librarians with tools to implement promising practices in this area. Finally, this report discusses areas for future research in the context of STEM education and programming in public libraries. While more research is needed to determine which activities, programs, and services are best for historically underrepresented K-12 populations, it is clear that public libraries hold great promise for the future.

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