Girls, Equity and STEM in Informal Learning Settings

A Review of Literature

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Abstract

This review was originally intended to focus on research findings about informal STEM programs for girls in museums and science centers written in English, however, the paucity of such focused research resulted in broadening the scope to include any research about informal STEM programs for girls written in English. In all cases, the relevance to museum practices was a consideration for inclusion. The scope was also expanded to include results from evaluation studies.

Requests for studies to include were sent to all Girls RISEnet planning committee members, and to over 20 other professionals around the globe who are working with girls in science. These requests were received with great interest and willingness to cooperate, though few programs had written research or evaluation reports to share. Most of the evaluation findings are not generalizable beyond the specific program being described, but they do collectively provide guidance for practice and directions for research and were considered for inclusion in this review.

This process yielded over 100 items that appeared relevant; upon reading the manuscripts, 70 provided information relevant to this review and are directly cited in the text. Those that were eliminated were either older than 2000, did not focus on girls or were focused on schools. In a few instances, reports dated earlier than 2000 are included because they spoke so directly to the topic at hand.

Based on the review it is concluded that the available literature strongly supports the appropriateness of museums and science centers as places for housing effective informal science programs for girls. Relevant and adaptable content increases the chances that girls will be motivated to participate in such programs as does the student-centered, hands-on, project-based approach that emphasizes collaborative teamwork in a low-pressure setting preferred by girls. The longer-term commitment by participants, and the sponsoring institutions, in these programs fosters close positive relationships with peers who share an interest in science. Positive relationships with well-trained professional staff as well as with working scientists fosters the development of girls' science identities, a central factor in the decision of saying “yes” or “no” to continuing in the science pipeline.

The literature further suggests that practitioners and researchers need to be attentive to several factors – in addition to the particulars of individual program designs and implementation – when attempting to address gender inequity in science. These are: the influence of family members in supporting interest in science; gender-related choices made about exhibition content and design; public perception about the role of women in science; and overall institutional commitment to gender equity.

Finally, implications for practice are offered and it is suggested that the science experiences designed by museums and science centers include evaluation and research components. Virtually every topic discussed in this review could benefit from additional research, particularly if that research is rigorously designed to go beyond description of individual programs and examines programs at multiple sites in order to increase generalizability of results.

INTRODUCTION

Overview of the Problem: Representation of Women in STEM

The under representation of women in science classes and STEM careers continues to be an issue of compelling puzzlement. Inherent gender differences have been ruled out by the vast majority of scientists given studies that demonstrate that younger boys and girls are similarly interested in science, and even that girls get better grades than boys in science. Yet high ability girls often do not have correspondingly high levels of confidence in their ability to do science (Baker, 2013), which may be one of the contributors to the findings that the standardized test score difference between boys and girls is not definitive, varying by year and geographic location, though boys appear to do better at the extreme high end of the distribution (Ceci and Williams, 2009).

Price (2013) found that underrepresented minority groups, including women, are generally very slowly catching up with their white, male peers. Yet it is still undeniable that proportionately fewer girls than boys persist in the STEM "pipeline" once they get to college and of those who do persist through graduation, many leave the STEM career path. European women account for 36% of PhD graduates but only 11% of full professors in science and engineering according to the European Commission She Figures 2009 (Roughneed, 2011). Ceci and Williams (2009) note that women are highly underrepresented as faculty members in two- and four- year colleges and universities. At the top 50 U.S. universities, the proportion of women a the highest ranks—full professors, directors, chairs and deans - range from 3.7% to 15% in a 2005 NSF survey. Once hired, women are 2.8 times more likely than men to leave STEM careers for other occupations. Women are also more likely to abandon high math-intensive fields than they are to abandon less math-intensive fields (Ceci & Williams, 2009).

While the exact numbers keep changing regarding girls' and women's performance on standardized tests, in school science courses and at pursuing STEM-related careers, some generalizations about women and their STEM-related choices are emerging. Ceci and Williams' review (2009) of over 400 primary sources from the fields of endocrinology, economics, sociology, education, genetics, psychology and cognitive neuroscience indicated that the evidence suggests that biological (boy/girl native ability differences) or social factors (sexism and prejudice regarding girls and women) seem to account for a small amount of the variance when looking at women's choice of whether or not to persist in STEM careers.

Personal family choice appears to be a much more significant factor in the decision to pursue high level careers in math-intensive fields of computer science, chemistry, physics, economics, accounting, statistics, engineering, math, operations research. The literature further indicates that some high-ability women have more options than do high-ability men. "Women are far more likely to be equally talented in both math and verbal domains simultaneously, giving them more options to enter non-math fields than are available to men" (Ceci & Williams, 2009, xiii). Margolis & Fisher (2002) also found that most women consider a range of factors when deciding what fields to pursue. Among the women choosing to major in computer science, for instance, five different factors were considered by over 30% of women; for men, the only factor considered by over 30% was "enjoyment of computing." The study was conducted with 100 male and female computer sciences students at Carnegie Mellon University and carries the title “unlocking the clubhouse,” in reference to findings that speak to how science training institutions and work environments are structured to more readily allow men, and their preferences and needs, claim the realms of power and success.

Schools and work places are not the only places where girls and women encounter and engage with science. Though the vast majority of research about science training, identity and career paths focus solely on those two settings. Increasingly, policy makers, scientists and science educators are becoming aware of the considerable amounts of learning that take place during out-of school time and in informal (non-school) settings.

Laursen et.al. (2013) conducted a survey of over 400 out-of-school time science programs and found that they took place in a range of settings:

26%	University or college
25%	Nonprofit organization
15%	**Museums or science centers**
12%	School district
8%	**Aquarium, zoo, planetarium**
8%	National youth organization
3%	Private sector organization
2%	Government lab

It is well documented that designed environments such as museums, science centers, zoos, and aquariums contribute to all six strands of informal science learning in the following ways: 1) interest in science is kindled by visiting; 2) scientific knowledge is gained; 3) scientific reasoning is engaged in, particularly when exhibits are interactive; 4) reflection on the science process occurs when exhibits give visitors opportunities to do so; 5) science processes are actively experienced; and 6) science identity is developed as visitors identify with subject matter they come to love (National Research Council, 2009, 127-162). The availability of informal science learning experiences begs the question: are the patterns of girls' choices and under- representation associated with their engagements with formal learning settings echoed in informal settings?

The 23% of programs offered by museums, science centers, zoos and aquariums were notable for the diversity of participants – 58% girl and 51% other than white registrants. They were also highlighted by the authors for the positive characteristics of program design and outcomes attributable to the presence of dual expertise in science and education (Laursen, et. a., 2013). Given the substantial number of science programs for girls in these setting, the purpose of this review was to accumulate and synthesize what is known about the effects of museum and science center experiences on the science-related identity, knowledge and STEM career choices and pursuits made by girls and women.

Parameters of the Review

This review was originally intended to focus on peer-reviewed, published research studies about the features and outcomes of informal STEM programs for girls offered by museums and science centers. However, it quickly became apparent that the number of such studies available for review was much like that faced by Murphy & Whitelegg (2006) who began with a desire to look at UK research about girls and physics aged 11-16. The paucity of such focused research caused them to widen the geographic scope of the search to international research and the age range of to girls in science, primary to post-16. Similarly, the scope of this review was widened beyond museums and science centers as settings, to include research about informal STEM programs for girls that had qualities similar to the hands-on, inquiry approaches to science that underpin museum and science center programs. In practice, though a program may not be housed at a university or youth center, it is fairly common to find that the experiences include use of activities and instructional materials produced by museums as well as visits to science centers museums, zoos and the like. In all cases, the relevance to museum practices was a consideration for inclusion. The scope was also expanded to include results from evaluation studies. In the early stages of searching the literature it became evident that evaluation reports – both published and unpublished – were a repository of information about what is becoming known about museum and science center program features of best practice and success.

The review is international in scope, with the caveat that material reviewed needed to be available in English. Members of the Girls RISEnet planning committee were instrumental in providing guidance and contacts for locating relevant projects and materials in Europe, Latin American and the Caribbean.

Requests for studies to include were sent to all planning committee members and to over 20 sources they recommended to the authors. These requests were received with great interest and willingness to cooperate, though few programs had written research or evaluation reports to share. Most of the evaluation findings are not generalizable beyond the specific program being described, but they do collectively provide guidance for practice and directions for research and were considered for inclusion in this review.

The process of gathering manuscripts yielded over 100 items that appeared relevant; upon reading the manuscripts, 70 provided information relevant to this review and are directly cited in the text. Those that were eliminated were either older than 2000, did not focus on girls or were focused on schools. In a few instances, reports dated earlier than 2000 are included because they spoke so directly to the topic at hand.

Structure of the Review

Early on in the review process, it became clear that definitions of the domain of science and what was considered to be a science curriculum were not consistent throughout the literature. In fact, one of the distinguishing features of museums and science centers, is that their approach to the content and study of science is different from that taken in most school settings. The first section of this review addresses this issue. The review also revealed an unmistakable alignment between features of museum programs and research-supported characteristics of successful out-of-school programs. The second section of the review describes the features of science center and museums programs and settings that are especially conducive to introducing and supporting girls in science.

The ways girls think about, value and approach science in museum and science center settings are mediated in many ways, chief among those mediating factors are family interactions, design features of exhibitions and public perceptions of women as scientists. These topics are the focus of section three. The concept of science identity is crucial to understanding why girls do or do not enter and pursue the STEM pipeline. Section four examines what is known about how museums and science centers can play a role in the development of interest in science.

Organizational policies and structures also influence the degree to which museums and science centers can effectively address equal access and success for girls in science. Section five addresses this area. There is little peer-reviewed research on this topic, but many evaluations address the topic, and there is now a critical mass of experience-based knowledge to inform practice and future research.

The final section presents implications for practice and research, with a particular emphasis on how exhibitions and programs in museums and science centers can suggest new directions for understanding, addressing and studying the continuing discrepancy between the numbers of men and the numbers of women who study and pursue STEM careers.

Science: Different Approaches to What It Is and How It Is Taught

It is not an oversimplification to say that there are two predominant approaches to the way the domain of science is described and the ways science is taught. Varied terms are used to talk about them. We will here refer to them as *Science in the Abstract* and *Science in Context*. In the former, science is conceptualized and taught as the disciplines of biology, chemistry and physics, for instance. In the latter, an understanding of and exploration of science is embedded within a real world issue or area of investigation of personal interest such as water conservation or building a tall structure. The distinction is helpful when examining science and its appeal in formal and informal learning settings because one form appeals much more to girls than does the other.

The science taught in traditional formal settings tends to be presented as Science-in-the-Abstract. With this approach, the beauty of scientific tests and explanations are seen as ends in themselves. Abstract Science is science for science sake. Connections to everyday life outside the learning environment, usually a classroom, are of little or no interest. Pedagogy for Abstract Science tends to depend on one-way transmission from teacher to student and on the acquisition of information. Some of the disciplines that lend themselves to the abstract approach are physics, chemistry, engineering and math. Abstract Science approaches, in general, have difficulty in gaining and retaining the interest of girls

Science-in-Context is science that is seen as related to everyday real world problems and issues. The practicality of Context-Focused Science is more obvious to learners, and girls particularly find this kind of science more interesting (Uitto et. al., 2005). Environmental science, animal husbandry, and health sciences are some of the subject areas that fall into this category and that are more appealing to girls (Archer, et. al., 2013).

There is a high correlation between framing the study of science as science-in-context and approaches to teaching and learning that include greater proactivity by students as they development and execute projects that they themselves devise. This is not to say that physics or computer science inherently cannot be taught in ways that elicit more inquiry from students and reveal applications more obviously. Hands-on, project-based activities that address issues and problems which learners see as relevant to themselves, their families and their communities are often multi-disciplinary in focus and because of their familiarity and importance to learners, engender higher levels of interest and accomplishment. As indicated below, research indicates that such an approach is of greater appeal to girls – <u>and</u> to boys. However, particularly in formal learning settings, this approach simply is not the norm (Osborn & Dillon, 2008).

A recent large-scale study in Ghana highlights the importance of the Abstract/Science-in-Context distinction when approaching science education (Anderson, 2006). It also indicates the importance of clarifying what is meant by “science” when talking about science-related interests and experiences. Anderson administered the standardized Relevance of Science Education (ROSE) survey made up of 250 closed ended 4-point Likert-type items that related to aspects of science and technology to 1027, 14-16 year olds in all 12 districts in the Central Region of Ghana in 2003.

Of particular relevance to this review, he found that the ten top out-of-school activities for his respondents were shared across gender.

> "Both genders had been involved more in activities, such as cooking a meal; making a fire from charcoal or wood; preparing food over open fire or stove burner; experiencing illness and getting medical treatment; and also experiencing nature or science through books, magazine, films, and TV programmes. Furthermore, they had a lot of experiences in using measuring ruler, tape or stick to measure and plant seeds and watch them grow. Some of the above activities for which both boys and girls claimed to be involved most often, appear closer to the curriculum contents in physical and biological sciences" (Anderson, 2006, 242).

Based on responses to questions about what science content students would like to learn and how youth perceive school science, he concluded that students perceive that the traditional curriculum reinforces the masculine characterization of science as abstract and disconnected from social and environmental concerns. It also associates science education with pedagogy of telling or transmitting knowledge (Anderson, 2006, 295).

For girls, the standard science curriculum and methods of instruction are far from ideal. Schools tend to emphasize Abstract Science that often is not obviously related to real world issues and problems. Generally, factual information is delivered to students by authoritative sources (teachers and texts) to be memorized and given back on standardized tests. There is an emphasis on competition rather than cooperation that also generally works against girls (Wilkins, et.al. 2005). Contemporary science developments and issues are often not addressed as many official lesson plans and some science standards remain focused on 19^{th} and 20^{th} century scientific achievements (Osborn & Dillon, 2008). The exploration of original student-generated research questions as a way to experience science as it is practiced by working scientists is extremely rare (Lave & Wenger, 1991). Study of scientific principles in an abstract vacuum rather than in the context of recognizable real-world issues along with little mention of science's humanitarian and cultural value is another reason school science fails to engage girls (Osborn & Dillon, 2008).

In addition to the abstract content and authority-focused pedagogical approach, the formal school science setting is often socially detrimental for girls (Tate & Linn, 2005). When girls arrive at their first academic courses they are often behind their boy counterparts in terms of relevant science experience (Margolis & Fisher, 2002). Teachers not sensitive to this initial girl disadvantage may exacerbate the problem as more aggressive boys dominate limited equipment, relegating girls to the role of note-taking, observer and bystander roles (Milgram, 2011). The TWIST (2012) project, designed to help teachers recognize the importance of understanding how gender might influence how students approach and learn science, is a step in the right direction.

Summary

The manner in which science is introduced has an effect on inspiring, developing and maintaining girls' interest and pursuit of science as an area of study and as a career. The traditional ways that science content has been organized for instruction and the associated approaches to teaching and demonstrating interest and competence are antithetical to what is known about what works to capture the attention and talents of girls and women.

The next section describes the types of science and features of learning environments and experiences that do spark girls' interests and support their exploration of and interests in science. There is also discussion of the alignment between those girl-supportive features and approaches to teaching science in museums, science centers, zoos and aquariums.

Features of Museums and Science Centers That Are Conducive to Girls in Science

This review has revealed that there is not much research that demonstrates a direct link between specific program settings (i.e., museums, science centers, community centers) and program outcomes for girls related to science. There is, however, considerable agreement among experts that museums and science centers do contribute to science learning. There is also a wealth of descriptive evaluation work that documents the design features of successful STEM programs for girls as well as agreement that programs that take a positive youth development approach to their design and implementation have the longest lasting effects on participants.

This section describes the kinds of learning that has been established as taking place in museums and science centers, outlines what is known about the features of successful STEM and youth development programs, and concludes with the argument that because of the nature of the content, teaching approaches and relationships found in museums and science centers, they are ideally suited to contribute in significant ways to bring more girls and women into science and STEM careers.

Museums and Science Centers as Places for Learning Science

Based on an exhaustive review of learning in informal settings (National Research Council, 2009), it was concluded that designed environments like museums, science centers, zoos and aquariums contribute to all six strands of informal science learning in these ways:

- Interest in science is kindled by visits;
- Scientific knowledge is gained;
- Scientific reasoning is engaged in, particularly where exhibits are interactive;
- Reflection on the science process occurs when programs and exhibitions provide opportunities to do so;
- Science processes are actively experienced; and
- Science identity is developed as visitors identify with subject matter they come to love.

Importantly, STEM programs in museums and science centers, like other OST (out-of-school-time) programs are *not* like school. Calabrese and Brickhouse (2006) single out the value of being in the midst of the real community of practice that is afforded to those who are introduced to science in the presence of exhibitions, collections and scientists. This and other distinctive features make museums and science centers especially conducive to providing a setting and approaches to learning that are appealing to girls. This is because . . .

> "… most OST environments are low-stakes (non-evaluative) environments, they provide opportunities for students to play or experiment with science, taking on new roles and stances that may be less accessible or possible in school settings – where there is often more pressure to follow particular procedures

or arrive at specific answers. This may be *especially important for students who have been discouraged by school science and might have self-identified as not competent or interested in science; such students, it has been shown, are disproportionately female or from non-dominant cultural communities."* (emphasis added)
(Bevin et.al. 2010, 3)

There is some evidence that Bevin's hypothesis that out-of-school settings, and especially museums, spark and develop girls' interest in science. McLaughlin (2005) suggests that a large part of the success of a "Girls in Science" science program for low-income, inner city junior high school girls was that more than half of the sessions occurred at the San Diego Zoo. In a recent retrospective study of six successful girl-focused STEM informal science programs based in museums, McCreedy & Dierking, 2013) found that 53% of program participants went on to become STEM majors in college, compared with a national average of 15% of first-year female undergraduates. Post program surveys from participants in The Miami Science Museum's SECME RISE four-week Summer Leadership Academy indicated that 86% of participants intended to pursue a STEM career and 52% claimed that the program had resulted in a change in their career plans (Jarvis, 2002).

Content in Successful STEM Programs for Girls

Relevant. In successful informal STEM programs, participants perceive the relevance of the content to their everyday lives. Rather than studying environmental issues in the abstract, they tackle specific problems such as pollution in a stream that runs through the community. Using scientific principles, tools and techniques they experience the thrill of scientific inquiry as they work to understand the problem, work toward solutions (Baker, 2013; Gibson & Chase, 2002) and feel that they are making a real difference (Franscali & Froschl, 2006). Weisgram & Bigler (2006) found that girls' belief in the altruistic value of science predicted their interest in science. Middle-schoolers felt most identified with science when they could relate it to their personal lives (Bacu & Calabrese-Barton, 2007; Wilkins, et.al., 2005). One girl said she felt like a scientist when she used what she'd learned in science class to teach her cousin to avoid junk food. Some boys in their study became enthusiastic about science when they could relate it to sports, such as designing an experiment to measure heart rate increase from vigorous physical activity. A review of the content of museum, science center, zoo and aquarium STEM programs as well as satisfaction ratings from program evaluations support the claim that the content of the programs are seen as relevant and of personal interest to participants. Yet, one study of sisters with similar backgrounds provides the caution that even a similar program experience can result in different perceptions about the relevance of science to ones life (Wheaton & Ash, 2008).

Flexible/Adaptable. The flexibility of a museum based informal STEM program is another huge asset when compared with other settings. Curricula can be developed that fosters understanding science in contexts that are of known interest to girls, such as topics related to health and caring (Archer, et.al. 2013). Contemporary science issues in the news such as neuroscience or molecular genetics can be incorporated, whereas, as Osborn & Dillon (2008) note, school science focus is generally on achievements of the 19^{th} and 20^{th} century. When it comes to adapting a program's focus, the museum-based program is like a small and crafty speedboat, compared to the ocean liner of the school system.

Appropriate Level of Difficulty**.** Effective informal science programs for girls need activities that are the appropriate level of difficulty (neither too hard, nor too easy) because perceived competence is an important part of intrinsic motivation (Deci & Ryan, 2002). Even with all-girl programs, the girls are often not as confident as their abilities suggest that they should be. With co-ed programs, it is easy for girls with shaky self-confidence about their science ability to be negatively influenced by the presence of boys who can dominate the scene if not kept in check. The beginning phase of a program is a particularly sensitive time. For example, often when the boys arrive in computer programs and classes they already know a lot from years of tinkering at home, often with their father's guidance (Margolis & Fisher 2002). This difference in science experience contributes to girls beginning their science studies with a deficit in what Taasoobshirazi & Carr (2008) call "science expertise" which one develops by devoting time and effort to deliberate practice.

Girls also care about the applications of the science they are learning. Their preference for science-in-context, makes it a good idea to introduce ideas about why a particular area of science is relevant in daily life before getting into complicated, and perhaps difficult, technicalities. Assignments need to be developed that take into consideration girls who might be highly capable learners but lack the advanced knowledge, experience and comfort that some of their peers bring to the program. Baker (2013) noted the importance of attending to group formation in co-ed learning situations so that girls are not left to observe and take notes while the more aggressive boys work the equipment. Making all-girl teams is one way around this problem, as is making both boys and girls aware of the issue and monitoring their behavior (Milgram, 2011).

Approaches to Teaching and Learning in Successful STEM Programs for Girls

Successful informal STEM programs eschew the "transmission of information" model that calls for a focus on teacher talk and student note-taking. Rather the emphasis is on project-based, hands-on, student-directed inquiry, often carried out collaboratively, with the help and guidance of working scientists and mentors in a low-pressure test-free environment (Osborn & Dillon, 2008). Any informal STEM program for girls in a museum or science center would want to build these elements into the program.

Baker (2013) reviewed the literature about curriculum and pedagogy in school settings that increase girls' interest in science. He concluded that the elements of effective practice he discovered match those of effective informal STEM programs.

Hands-on. When asked in post-program surveys and interviews, participants invariably give very high marks to the hands-on aspects of their program experiences (DeHaven & Wiest, 2003; Fanscali & Froschl, 2006; Ferriera, 2001; Gibson & Chase, 2002; Liston, et.al. 2008; Osborn & Dillon, 2008). It appears that the use of hands-on activities to learn is intrinsically more interesting and appealing to young girls, when compared with less active ways of engaging with science.

Student-Centered. Successful informal science programs for girls focus on the girls as much as they do on the science. They are sensitive to the cultural background of the participants (Valla & Williams, 2012). Using an inquiry-based approach (Sandoval, 2005) to study problems that are real to the girls (Liston, et.al. 2008), they respect the learner and let her play a major role in the direction of her learning (Baker, 2013).

Collaborative Teamwork**.** Girls consistently give high marks to working cooperatively. When Liston et.al. (2008) surveyed 123 representatives who were most familiar with their STEM program's structure and goals “opportunities to work with others” was rated among the top three practices contributing to program success. Girls surveyed by DeHaven & Weist (2003) rated group-work in a supportive environment as an important aspect of their non-school based science summer program as did those in Gibson and Chase's longitudinal study of a girls in a science program at Hampshire College (Gibson, & Chase, 2002).

Informal-Low Pressure Setting**.** By definition, informal learning environments are low-pressure. As education environments they are test-free, without need for externally imposed deadlines. In the absence of external pressures, learning is based on intrinsic motivation. That is, students engage in the program because they find the activity, in itself, interesting (Deci & Ryan, 2002). Girls studied by DeHaven and Weist (2003) found that working without grade pressure greatly reduced their anxiety compared with their school experiences.

The Importance of Relationships in Successful STEM Programs for Girls

To the extent that museum and science center programs involve a longer over-time commitment and tend to be staffed with full time, well-trained staff, they can be expected to have a greater impact on developing and maintaining girls' science identities, an important factor in girls' choices to pursue STEM coursework and STEM-related careers. The distinct advantage of long-term programs is the opportunity to develop relationships.

Peer Relationships**.** Programs that include a youth development framework offer girls the opportunity to receive emotional and moral support in the context of supportive relationships. The sense of belonging that develops in these programs helps keep participants motivated to continue to participate (Fancsali, 2002). Developing academic and social skills in a context of close relationships with peers increases self-confidence in one's self as a person who can do science. For example, for a summer STEM program for middle-schoolers in Nevada, the residential component was extremely important because it allowed girls who were spread out across the northern part of a sparsely populated state to bond with others who shared their interests (DeHaven & Weist, 2003).

Findings are mixed on the benefits of single-sex groupings for science classes and programs. Whitelegg (2013) reports that attending a single-sex school resulted in approximately 2.5 as many girls enrolling in A-level physics when compared with those in co-ed institutions. On the other hand, Hughes and her colleagues (2013) found no difference in effects on science identity when they compared single-sex and co-ed STEM camps.

Staff. Highly qualified, well-trained staff are an integral part of any successful informal STEM program for girls (Birmingham, et. al., 2005). Staff need to know STEM subject matter as well as being adept at group facilitation and good at relating to youth. Based on a review of STEM intervention programs for underrepresented youth, Valla and Williams (2012) concluded that youth particularly benefit from relationships with individuals who monitor and guide them over an extended period of time, sometimes, even after the program has ended. Help with college applications and with the transition to the post-secondary phase to the STEM pipeline also helps student stay on track toward science careers.

Mostache and her colleagues (2013) examined three effective STEM programs for girls: *Techbridge*, aimed at grades 5-12; *Go Techbridge*, aimed at middle-schoolers; and *Access for Young Women* for grades 7-12. All of the programs enhanced girls' comfort with STEM topics and activities and increased their knowledge of STEM related careers. All three place emphasis on continuous evaluation and training for leader-facilitators.

Gibson and Chase (2002) undertook a study that is rare for it's inclusion of a control group made up of students who applied for a girls summer STEM program but were not accepted. The data from attendees in the years1992-1994 indicated an interaction between science attitude scores and the year attended and suggested just how important quality staff is to program success. Attitude scores for participants in the 1993 group declined while those for participants in the other two years did not. There was also a significantly greater decline in science career interests for the 1993 group compared to the others. In 1993 Hampshire College allowed some teachers in a summer workshop of their own to conduct some of the STEM classes. The teachers were on campus to learn to use an inquiry based approach to science. The data on the decline of student science attitude and career interest strongly suggest the importance of trained staff in out-of-school STEM programs, a finding that deserves to be further tested.

Role Models**.** Halpern, et.al. (2007), review of literature revealed five recommendations for successfully encouraging girls in math and science. Among the recommendations was that of exposing young girls to female role models who have achieved in science and math as a way of encouraging belief in women's abilities in math and sciences. However, Halpern and colleagues considered the research support for this notion to be weak, noting the need for further research on the effects of role models.

Program administrators surveyed by Liston et.al. (2008) reported that mentors are an important aspect of their programs. They thought mentors who are close in age to student participants are most effective, a notion supported by Jarvis' (2002) evaluation of a successful program designed to raise girls' interest in science and engineering. Mentor age and status (graduate student, young professional, etc.) are variables that call for research.

Of the successful informal STEM programs examined by Mosatche and her colleagues (2013), both *Techbridge* and *Access For Young Women* considered it important to work collaboratively with museums and other organizations in order to secure participation of scientist role models**.** So important are these relationships that a major San Francisco gender-equity initiative is based on the triadic relationship among girls, teachers and scientists (Chatman, et. al., 2008).

Longer-Term Programs Foster Positive Relationships**.** An important element of museum STEM programs is that they tend to offer longer time for engagement than those based in other types of institutions (Laursen, 2013). Valla and Williams' review of K-12 STEM interventions programs found that the most successful programs included, among other things, support from peer relations and quality leadership “from people who mentor and guide students, as a group and individually, over an extended period of time” (Valla & Williams, 2012, 42)

The New York Hall of Science Explainer program increases science identity by providing direct access to a science teaching training program that builds science knowledge and communication skills. An important contributor to this program's success is the fact that it is encourages multi-year participation with increasing involvement and responsibilities for participants (Gupta & Siegel, 2008; New York Hall of Science, 2011).

Features of Well Managed STEM Programs for Girls

A number program management variables influence the success of informal science programs for girls. The following list can serve as a checklist for organizations attempting to develop an ideal environment for such programs.

Administrative Considerations

- Procure diverse funding sources
- Be active in networks and build partnerships with other relevant organizations to facilitate recruiting of diverse participants for programs
- Provide resources; sufficient and good quality equipment, supplies and space. In the ideal situation, an informal science program would have its own dedicated space.
- Be aware of cost issues for participants and efforts to make programs free or low-cost, offering scholarships where necessary and appropriate.

Features of Staff Members

- Full-time positions with the institution. Stability is important in programs, particularly if they are longer-term and reach at-risk youth who live in families and communities that do not provide stable environments for them. Staff needn't be assigned full-time to the programs but should be people with long-term commitments to the institution.
- Knowledgeable about science as well as group and personal development.
- Trained in facilitation techniques in order to facilitate student-centered learning.
- Adaptable—Able to respond creatively in order to work with participants on topics of participant interest and science-related issues that arise in general society and in the contemporary science community.
- Women staff as role models.
- Older students, possibly program alumni, to serve as mentor-role models.
- Women scientists as adjunct participants who may serve as guest speakers and/or mentors on projects, also as role models who can help girls define the science community of practice as inclusive of women.

Summary

The available literature strongly supports the appropriateness of museums and science centers as places for housing effective informal science programs for girls. Relevant and adaptable content increases the chances that girls will be motivated to participate in such programs as does the student-centered, hands-on, project-based approach that emphasizes collaborative teamwork in a low-pressure setting preferred by girls. The longer term commitment by participants, and the sponsoring institutions, in these programs fosters close positive relationships with peers who share an interest in science. Positive relationships with well-trained professional staff as well as with working scientists fosters the development of girls' science identities, a central factor in the decision of saying “yes” or “no” to continuing in the science pipeline. Finally, the success and long term stability and sustainability of programs are correlated with decisions about how the programs are administered and managed.

These findings from the literature about effective STEM programs for girls provide guidance for museum and science center practitioners and suggest areas for program improvements and further investigation and research.

The Role of Mediators When Girls Are Introduced to Science

Being introduced to relevant science content, having an opportunity to be an active learner and developing relationships that support an interest in science are not, in and of themselves, all that is necessary to address the barriers and complications girls face in their pursuit of interest in science.

There are people, organizations and social norms that mediate what is available for girls and how well it meets their preferences and needs. Four such mediators, particular to museum and science center settings, were identified during this literature review: family members; exhibition designers; public perceptions of woman as scientists; and the gender-equity culture within organizations that offer science programs and opportunities for girls.

Family

Parents not highly aware of how they interact with their children around science, appear to be unconsciously influenced by social norms. Crowley, et.al. (2001) found that parents with children during informal science activities explain more to boys than to girls. The difference was noted with children in groups as young as 1 to 3 years, and the difference was observed with both mothers and fathers.

Another study found that family conversation with children high and low in dinosaur knowledge differed when the family visited a dinosaur exhibit.. Parents with “novice” children engaged them in learning conversations. Parents with “expert” children who knew a lot about dinosaurs from other sources were more likely to encourage the “experts” to recite facts already known rather than urging them to learn new things from the exhibit (Palmquist & Crowley, 2007). Both of these studies suggest the importance of making parents aware of their interactions with their children around STEM topics in hopes of making positive changes.

Taylor (2002) reviewed literature on the role of gender and gender interactions at science museums on learning in these settings. He notes that a variety of social interactions mediate experiences in museums settings (e.g.: parent-child dyad, sibling interaction, friends) For example, mothers and daughters are more likely to follow male family members through science museums and in mixed gender groups, boys might displace their sisters in turns at exhibits.

Findings on the subject of family interactions and influences have not been consistent. It is interesting to note that an earlier study of family behavior in exhibits in four science museums (Borun & Chambers, 1999) indicated “there does not seem to be a problem of biased behavior toward boys and girls on the part of adult and female visitors to science museums. All participate fairly equally in the family learning experience.” The role that families play in supporting and developing science interest and pursuits remains an area for further research as well as an area for exploration by program and exhibition planners.

Exhibitions and Program Developers

Dancu (2010) found that when exhibits incorporated features deemed female-friendly it resulted in significantly higher engagement for girls, evidenced by greater attraction and time spent. There were three categories of female-friendly features: 1) Building for collaboration; 2) Making connections; and 3) Gender balanced representation.

- Building for Collaboration features were designed to: 1) encourage interaction and collaboration, (e.g. two simultaneous parts of an activity, two-person benches, multi-user/sided); 2) avoid speed or competition-based activities, (e.g. two simultaneous, collaborative parts of an activity, everyone wins, multi-outcome rather than succeed/fail); 3) enhance girls experiences when boys are involved in the activity, (e.g. two simultaneous parts of activity, incorporation of an observational aspect).

- Making Connections features were designed to: 1) connect to social or community applications, (e.g. solving social problems, offer links to relevance in everyday life); 2) provide the context surrounding concepts, (e.g. make interdisciplinary connections and connect with other exhibits, provide a story, tell history and contribution).

- Gender-Balanced Representations features were designed to: 1) emphasize cross-gender skills and preferences, (e.g. offer male-female aspects of one process such as mixing concrete and mixing cookie batter, use problems/examples from traditionally female-associated fields such as nursing, life sciences); 2) use female oriented language and aesthetics, (e.g. include females on the design team, balance words like *command* or *tackle* with words like *connect* and *embrace*); 3) highlight female role models and users, (e.g. use pictures and stories of young female scientists/mathematicians, provide pictures of female users).

Incorporating these female-friendly features did not appear to produce any unintended negative effects for boys. She concluded that “while the positive effects for girls were significant, it is important to note that they were not significantly more positive for girls than for boys; further research is needed to determine whether the female-friendly design features create a more equitable experience for girls, or a more positive experience for everyone” (Dancu, 2010, 1).

Greenfield (1995) examined the relative attraction of hands-on, interactive science museum exhibits for females and males. Studies have demonstrated that such exhibits can be effective learning experiences for children, with both academic and affective benefits. Other studies have shown that girls and boys do not always experience the same science-related educational opportunities and that, even when they do, they do not necessarily receive the same benefits from them. These early differences can lead to more serious educational and professional disparities later in life. Greenfield (1995) notes, “As interactive museum exhibits represent a science experience that is readily available to both girls and boys, the question arose as to whether they were being used similarly by the two groups as well as by adult women and men. It was found that both girls and boys used all types of exhibits, but that girls were more likely than boys to use puzzles and exhibits focusing on the human body; boys were more likely than girls to use computers and exhibits illustrating physical science principles. However, this was less true of children accompanied by adults (parents) than it was of unaccompanied children on school field trips who roamed the museum more freely" (Greenfield, 1995, p. 925).

Wohre and Harrasser (2011) examined the ways boys and girls experienced a hands-on experiment in a museum exhibition that was designed to be appealing to both boys and girls. In their study, 220 boys and girls in school groups visiting an Austrian museum were observed as they interacted with a technical object designed to teach them about color by allowing them to mix colors. Boys used the object for immediate play and invented their own way of using the object while girls often held back at bit at first while trying to grasp the purpose and idea behind it. Boys invented games such as seeing who could drain out his water fastest while girls asked questions like "What do you do this for?" and offered suggestions for improving the display. Overall the researchers concluded that boys were more playful (and perhaps more comfortable) and girls were more thoughtful in their approach.

The environment of the exhibition, *Mirakulosum,* of which the activity was a part, was purposefully designed to suggest multiple ways of knowing and thus attract the attention of those not necessarily drawn to science, *per se*. The color mixing activity was housed in a structure that looked like a witch's house described in fairy tales and included a 'cabinet of curiosities' look with strange containers displayed in an unordered way. Thus the exhibition suggested both pre-scientific and scientific approaches to discovery. The labels provided information such as: "historically, the best way to make red was to use lice blood". Museum educators were on hand to facilitate interaction, and it was noted that all of the children asked how the object worked before starting to use it.

These studies suggest possibilities for a rich program of experimentation for exhibition and program designers in museums and science centers that examine the effects of incorporating multiple ways of knowing, opportunities for collaboration and ways to increase interaction with activities, staff and other participants – all features of learning environments that are demonstrated to contribute to sparking and developing interest and knowledge among girls.

General, Public Perceptions of the Relationship Between Girls and Science

The overarching status of public perceptions of science and scientists is of great interest to those who work on STEM programs for girls. Even a recent study (Christidou, et. al., 2012) offered evidence of gender bias in its report that 73% Greek female teenagers drew a male when asked to draw a "researcher." This review of literature surfaced articles that recognized such gender bias and described efforts to influence public perceptions primarily through public information campaigns in the form of festivals, specially designated Gender Days, teacher training programs, and in one case, a museum exhibition.

The EU program, *Science: It's a Girl Thing,* is aimed at 13-18 year-old girls, especially those who might not initially be interested in research careers (EU Commission for Research and Innovation, 2012). In the program, online and face-to-face activities with women scientists are used in an attempt to inspire girls toward heightened interest in careers in science and engineering. The program includes day-long programs throughout the EU (Belgium, Austria, Germany, Italy, Netherlands, Poland, and more) featuring four components:

- Interactive and fun science experiments;
- Discussions with women scientists sharing their passion for science;
- Attending a stimulating lecture on the difference(s) or similarities between boys and girls in science; and
- surprise activities (one program featured a flash mob dancing in white lab coats).

In another large-scale program in Europe, the *Towards Women in Science and Technology (TWIST*) project exhibits and activities in museums and science centers focus on raising awareness about the roles and representation of women in science. The strategy is to inspire on-going discussion on issues of gender and science with the ultimate impact of changing views about what constitutes a scientist. Involving 11 European partners, activities include:

- Interactive dialogues
- Teacher training to increase teacher awareness of stereotypes and prejudices regarding men and women's career paths;
- Scientist speed dating, as a fun way to talk with scientists about their work, many of whom are women;
- Exhibitions featuring women scientists; and
- Gender Day activities, scheduled annually on International Women's Day.

These projects are relatively new, and no research reports were available at the time this literature review was conducted. One indication of the positive contribution attention to public perceptions can have on supporting girls' pursuits of science careers is the success of a science center program designed to raise interest in science and engineering where 86% of the participants indicated that they intended to pursue a STEM career. The program design included a Family Day. Nearly 100% of the girls' parents attended and witnessed the work and passion of the participants (Jarvis, 2002).

Organizational Cultures That Support Girls and Science

The TWIST project (TWIST, 2012) calls attention to the importance of an institution-wide culture that addresses gender inequity. Guidelines for institutional policies and practices that contribute to encouraging and supporting women in science cover all aspects of organizational life. A survey of 74 science centers and museums found that 70% considered gender as part of their core business; 50% had specific methods to ensure both genders were involved in all target audiences, and 42% have gender expertise on staff (Cacace & Colonnello, 2011). The same study showed a positive correlation between science centers and museums that show a strong orientation towards gender issues and those most prepared to be innovative in their role in the relationship between science and society.

The TWIST guidelines offer direction for institutions making a commitment to gender issues. The report notes the fallacy of believing that simply offering programs for girls is sufficient. Museums and science centers are advised to put a “gender filter” on all activities. Attention to gender equity cannot be isolated in one area of the institution. Gender-inclusive institutions can be identified by such things as: gender checklists for exhibitions and program design; gender-balanced management teams; attention to gender-sensitive language; pay equity; long-term gender action plan for staffing; training for awareness raising about gender issues; diverse work teams; flexible work schedules and other supports to promote work-life balance.

The overall institutional commitment to gender equity has the potential to mediate girls' experiences in relation to their feeling welcomed and supported to pursue their interests in science and science careers (Tate & Linn, 2005). The entire institution, not just a particular program, can influence a girl's STEM-related experiences and decisions.

Summary

The literature suggests that practitioners and researchers need to be attentive to several factors – in addition to the particulars of individual program designs and implementation – which influence efforts to address gender inequity in science. Of particular interest to those providing opportunities for girls in museums and science centers are: the influence of family members in supporting interest in science; gender-related choices made about exhibition content and design; public perception about the role of women in science; and overall institutional commitment to gender equity.

Museums and science centers are in a position to support girls as individuals – and to address some of the larger mediating factors that, if not intentionally addressed, work against the best interests of girls and of science. Research indicates that it is not simply liking science or being good at science that correlates with incorporating it into a girl's life or pursuing a STEM career. A girl needs to have a sense that science is important, that it matters, that women do it, and that she wants it to be a part of her life.

The next section of this review focuses on the importance of developing a science identity, the challenges girls face, and what works to establish a strong and positive connection to science for girls and women.

Development of Science Identity
A Critical Factor in Saying Yes or No to STEM

The concept of science identity is crucial to understanding why girls do or do not enter and pursue the STEM "pipeline." One might be said to possess a science identity if one sees one's self as affiliated with science, as one who seeks to perceive and understand the world as a scientist does, setting a high value on a rational-empirical approach to understanding and addressing problems. Persistence in the STEM pipeline goes along with having a strong science identity.

Science identity is more than liking science. Merely liking science, or being good at science, isn't necessarily enough to motivate girls to pursue STEM coursework and STEM-related careers (Lackey, et. al., 2007). Archer and her colleagues (2013) interviewed a sub-set of respondents to a large UK-wide survey about science-related attitudes. The girls in the interview sample were aged 10/11 and drawn from 11 schools around England and had reported on the survey that they did *not* aspire to science-related careers. The sample included a number of students who liked science and were capable enough at it, but simply felt that it was "not for me." These girls aspired to careers they saw as more compatible with a hetero-feminine self-concept, such as nursing, childcare and entertainment. On the other hand, Simpkins and her colleagues (2006), in a longitudinal study found that youth who believed they were skilled and had an interest in science were more likely to pursue the endeavor during adolescence than were their peers.

The Importance of Starting Early and Being Persistent

The research on science identity suggests that it can begin to develop early, can be influenced positively by informal STEM programs, and is not static but rather fluctuates, more so for girls than for boys, so that gains made as the result of positive experiences can be lost if not subsequently supported.

Simpkins and her colleagues collected survey data from 227 students in the 6th, and later in the 10th grades, to measure among other things, math self-concept, interest in science and attitudes about the importance of science. They found that out-of-school math and science activities up through the 5th grade, (prior to the first survey), predicted subsequent values and self-concepts of abilities (Simpkins, et.al., 2006, 78). Boys' math/science concept was more stable between 6th and 10th grades. Girls' tended to decline over that time span. Tenth grade math/science self-concept was a slightly stronger predictor of math and science courses taken, as indicated by 12th grade school records.

Further data suggesting the importance of starting early to develop the science identity, as well as its fragile nature comes from an evaluation of an informal summer science program for junior and senior level students in the Midwest. Stake & Nickens, (2005) found that having positive science peer relations before entering the program was related to positive expectations of self as a scientist. There were no male-female differences in this co-educational group on the pre-program survey. On the immediate post survey girls reported a stronger science affinity than the boys, but on a 6-month follow up the gains had disappeared and there were no male-female differences in perceptions of self as a future scientist. Lee's (2002) study of 320 male and female students in 10 summer programs revealed a positive influence on identification with science. His results indicated that "emotionally satisfying relationships centered on STEM activities and discussions positively shape students' likelihood of thinking of themselves in STEM terms and engaging in STEM activities" (Lee, 2002, 349). The programs had more influence on the girls' science identities suggesting they are amenable to interventions, but in this case, the changes were temporary.

The Need for Support

Additional research suggests that the presence or absence of support from home and school can influence science identity and the concomitant tendency to pursue STEM coursework and a STEM-related career (Fouak, et. al., 2010). Barton et.al. (2013) conducted in-depth case studies of two inner-city, African-American middle school girls. Diane, who liked science because it 'helped her figure things out' was not considered a strong student in the traditional sense. She would rather hand in work late if that's what it took to get it right. During one lesson on invasive species she was the last to complete the assignment, which led her teacher to focus on the fact that she usually needed extra time. When the researchers asked Diane what the assignment was about, she was able to explain various invasive species in depth. By contrast, when the researchers asked a top student (who gets As and efficiently completes work and gets it in by the deadline) about the assignment, she could say only: "I don't know, it was about invasive species" (Barton et.al., 2013, 39). Despite what appeared to be a deep engagement in science, Diane was not recognized by her peers or teacher as a strong science student. Rather she was thought of as a so-so student who did not care about grades. Her lack of support at school in relation to science led to her eventual lessened engagement. In Chantelle's case, with some of Diane's same issues, her work as a budding scientist was urged on by school administrators and teachers. Their attitudes allowed Chantelle a safe place to try the kind of science identity she was building after school and at home and she maintained her strong science identity. The authors conclude that schools need to be alert to the strictures of the way "things have always been done," and recognize opportunities to help students develop and create science identities by letting them model the behaviors of real scientists if the students are so inclined.

Family support is also an important factor in the development and maintenance of science identity. Aschbacher et.al. (2010) investigated why some members of a diverse group of 33 high school students who were very interested in STEM disciplines dropped out of the STEM pipeline while others persisted. Based on survey and personal interview data, the students fell into three groups that differed in the support they received for their science identities.

- High Achieving Persisters got support for their science identities at home, at school and in extracurricular activities. "Many participated in compelling extracurricular opportunities where they apprenticed with STEM professionals, described as inspiring role models, who helped students find their strengths in science while practicing authentic work" (Aschbacher, et. al. 2010, 578-579).

- Low Achieving Persisters were mostly lower income girls who initially wanted to be doctors. They lacked the parental and professional support of High Achieving Persisters, maintained their science identities through support of siblings and non-parent adults and lowered their expectations to other science-related occupations such as lab technician.

- Lost Potentials perceived little support for their science identities from anywhere and dropped out of the STEM pipeline even though “most were capable and hardworking” (Aschbacher, et.al. 2010, 579).

Participating in the Community of Science Practice

The researchers concluded that compelling apprentice or internship opportunities facilitated by supportive parents is what set the High Achieving Persisters apart from the others. This distinction for High Achieving Persisters, highlights the importance of the involvement of scientists and doing real science work in informal STEM programs (Calabrese & Brickhouse, 2006). When young students engage in real science that involves testing original hypotheses by collecting and analyzing relevant data they are beginning their journey into what Lave and Wenger (1991) have termed the “community of practice” through situated learning. Learners begin as legitimate peripheral participants in ongoing practice and in doing so begin to take on the identity of the community of practice members. If the student-apprentices stick with it, eventually they develop into full participation. They become scientists. Lave and Wenger note the importance of genuine legitimate peripheral participation that can happen in informal STEM programs, as contrasted to school science. “...there are vast differences between the ways high school physics students participate in and give meaning to their activity and the way professional physicists do. The actual reproducing community of practice, within which school children learn about physics is not the community of physicists but the community of schooled adults” (Lave & Wenger, 1991, 99-100).

Project Exploration is a science program for teens that is built on a positive youth development model that involves teens, especially girls and minorities, in real science work as junior paleontologists in the field in places like Yellowstone and Puerto Rico. Youth also serve as docents in exhibitions. An evaluation of the first ten years of the program found that girls reported that Project Exploration opened their awareness to the possibility of pursuing science and increased their confidence regarding their ability to be successful in science. The study also reports that 40% of the girls who graduated as field program alumni chose to major in science (Chi, et.al., 2010).

Intrinsic Motivation

Using Hidi and Renninger's (2006) four-phase model of interest development, one can see how museums and science centers can play a role in the development of interest in science and creation of a science identity. Similarly, the Engagement, Capacity, Continuity Trilogy (ECC Trilogy) for success in science (Jolly, et. al, 2004) works from the assumption that development of a science identity takes place over time and requires more than being introduced to science in school. Students, both male and female, who want to become engineers, for instance, indicate more interest, perceived capacity and participation in out-of-school STEM-related activities (Weber, 2012).

According to Hidi and Renninger, the first two interest phases are situational. Phase 1, Triggered Situational Interest, happens, for instance, when a child is taken to a museum and shows interest in an exhibit on lightning. Phase 1 interest will pass fleetingly however, if there are not additional opportunities for engagement. Phase 2, Maintained Situational Interest, comes about when the child is taken back to the exhibition, perhaps comes across it in a science class or checks out a video or library book related to the topic. These first two levels of interest are fostered by the availability of resources in the child's community.

If that initial interest is to develop to higher levels, then according to the ECC Trilogy, it is essential for the child to have continued opportunities and to develop her knowledge and skills. The higher levels of interest involve science becoming a part of the individual. In the example offered here, when the child becomes interested enough in the topic to begin independently studying lightning and avidly wishes to learn about it and other weather phenomena, that is evidence of Phase 3, Emerging Individual Interest, be reached. This is the point where informal science programs can play an important role because this level of interest calls for external support, role models, and helpful peers and guides who can help with challenges that arise so that the young learner can persist through difficult periods that might arise.

Finally, Phase 4, Well-Developed Individual Interest, level is reached. This level of interest involves a relatively enduring predisposition to reengage with particular content over time. It's the feeling about science that someone with a strong science identity has. The person is self-motivated, highly curious, and loves the endeavor. At the highest level of interest development a person is intrinsically motivated. Social conditions that promote intrinsic motivation are: perceived competence, perceived autonomy and optimal challenges that are neither too difficult of too easy (Deci & Ryan, 2002). These social conditions are all fostered in effective informal STEM programs.

Summary

Early, and continual, engagement with science are essential to the development of a science identity – a way of defining the self that includes valuing science as a way of knowing, being fundamentally curious about the world, and having knowledge and skills that support exploration, investigation, and continued learning and understanding. Informal learning environments, such as museums and science centers, play a critical role in introducing young children to science in ways that are engaging and memorable. Further engagement with science, through program participation is known to increase girls' perceptions of themselves as scientists, though that immediate sense of affiliation can dissipate if not further supported.

The development of a science identity, and with it, an internalized motivation to participate, learn more and even pursue a STEM career, requires all three factors of engagement, capacity building and continuity of opportunities over time. It also requires those working with girls to collaborate with each other to assure that their individual efforts can be coordinated into comprehensive developmental experiences for girls (Falk, et. al, 2012). One program, or even occasional programs, will not be sufficient to support the development of a science identity that is essential to valuing and contributing to science.

Implications and Future Directions

To say that little is known about how museums and science centers can make a positive contribution to addressing the social issue of gender inequity in science would not be accurate. Many experienced and insightful practitioners have dedicated innumerable hours to designing and implementing STEM-related experiences for girls, and reflecting on their practices. Individual evaluation reports provide compelling advice from lessons learned.

Though the literature is rich with advice based on thoughtful practice and careful reflection, this review did not find many research studies that meet the criteria of methodological rigor, consistent operational definitions of key terms or peer review. The wealth of practice and exploration do, however, reveal promising avenues for research. With concentrated effort, precise research based on understanding about how museums and science centers contribute to gender equity in science could advance swiftly and dramatically.

Implications for practice and research are abundant throughout the sections of this review. A succinct summary of them is provided below under the headings of "Implications for Practice" and "Implications for Research." The section closes with thoughts about future directions to advance both practice and research.

Implications for Practice

<u>Content</u>. The available literature clearly suggests that the most successful informal science programs benefit from emphasizing science content that is related to recognizable real world issues and problems, that is, Science-in-Context. Rather than examining chemistry in the abstract, young girls are much more interested and motivated to learn when chemistry is used to detect possible pollutants in a neighborhood stream.

Connecting program content to a range of real-life decisions and actions is also advisable. Successful programs provide information relevant to pursuing a career in science. Understanding the value of science for personal health and safety and as part of responsible citizenship are also of interest to girls and women and can be important elements in any informal science program. Exhibitions and special events that emphasize the connection of science to everyday life will be better received by girls.

Content should include clearly-articulated information on the vast array of "STEM-related" careers. McCreedy and Dierking's (2013) assessment of six successful programs found that 17% of program participants felt that they were working in STEM-related careers, but when the US Bureau of Labor Statistics was consulted, it was discovered that 48% of participants were working in careers characterized by the Bureau of STEM-related. This suggests that even in otherwise successful programs, more attention should be given to this important topic.

Formats. There are important advantages to longer-term programs in terms of building relationships and helping girls develop their science identities. However, one-time "Science Day" events can serve the purpose of initiating interest in science that may become deeper with subsequent experiences. Interactive involvement that engages young girls is always a plus. It is also worth considering science topics that are generally of higher interest to girls, such as health and the environment, as a focus for exhibitions and one-time programs.

Relationships. Helping girls build relationship with peers who share their interest in science, adult staff, and science professionals should be a part of any informal science program for girls. Developing and sustaining strong relationships with women scientists in the institution and the immediate geographic area is important for engaging girls' participation in programs and development of science identities.

Implications for Research

Most of the evaluation and research to date is descriptive in nature. The available literature suggests that there is a strong need for rigorous research using experimental and quasi-experimental designs in order to increase confidence in conclusions about the impact museums and science centers are having in addressing gender inequities in science. In considering what the research agenda might include, attention could be given to:

The Universe of Activity. To better understand the impact of museums and science centers in the field of informal STEM programs, studies are needed to investigate how many STEM programs for girls based in non-museum settings are using museum instructional materials, museum visits and museum staff as part of their design. Many programs operated by colleges and universities, agencies (like the Girl Scouts), and other community organizations depend heavily on the materials and resources of museums and science centers. The role that such organizations play in STEM-related support for girls is currently grossly underestimated.

Multiple-Site Studies. At present, individual programs have been linked to increases in interest in science, attitudes toward science, development of a science identity and choosing to study science in college and pursue a STEM career. While it is helpful for programs to link their efforts to desired outcomes, the idiosyncratic nature of the program descriptions and designs does not necessarily advance knowledge in a way that contributes to development of guiding principles and theory about the ways museums and science centers can contribute to eradicating gender inequity in science. Conducting research that addressed the same questions and investigated the same variables and outcomes across multiple sites would advance knowledge – and improve practice.

The Array of Desired Outcomes. Desired outcomes for girls' informal science programs fall into three broad categories: (1) changes in science skills, behaviors and attitudes; (2) increased in general academic skills, behaviors and attitudes; and (3) positive youth development variables such a self-esteem and leadership (Archer, et.al., 2003; Chun & Harris, 2011). What is missing is an understanding of the how these discrete changes interact in creating more profound and long-lasting dispositions toward science. A thoughtful selection of outcomes and an understanding of the how various outcomes interact to result in the desired impact for girls suggest new directions for evaluation and research.

Concepts and definitions. Many concepts appear across program designs and evaluation studies. There is, however, little or no congruence in how the concepts are defined and operationalized. Several researchers have called attention to the need for development of precise and operational definitions of important concepts such as interest, curiosity, engagement and motivation (Lloyd, et. al., 2012; Phipps, 2010; Renninger, 2007). The results of this review verify that there are no common definitions or operationalization of key concepts, and future research could be directed toward addressing this situation.

One area of particular concern is the definition of STEM careers. McCreedy & Dierking (2013) found that there was a discrepancy between what researchers (and the federal government) categorized as STEM careers and what STEM program alumni saw as STEM careers.

Furthermore, while the pursuit of STEM careers is an important outcome, the activities of museums and science centers, as opposed to formal institutions of learning, brings attention to other desirable STEM-related outcomes for women. What for instance, are the effects of participation in science programs on girls' science identities and their attention to science-related social and community issues? Girls who might have dismissed science as something not of importance of interest to them, may not be on a trajectory toward becoming scientists, but they may be playing a vitally important STEM-related role in their families and communities.

A holistic view. All areas of impact due to the efforts of museums and science centers are not directly tied to the decisions, behaviors and choices girls make. There are factors outside of the control of individual girls and women that effect their ability to value and engage with science. An area for action and research that has not yet been investigated is how museums and science centers can influence the role of hard-to-change variables such as the highly demanding nature of the science profession (Ceci & Williams, 2009) and the notoriously girl-unfriendly environments in some STEM classrooms and labs, that deter young women from entering and staying with STEM careers.

Conclusion and Future Directions

Characteristics of successful informal STEM programs for girls readily lend themselves to implementation in museums and science centers. The potential for longer term programs led by professional staff that know STEM content and are trained in facilitation of student-centered learning, along with access to women scientist role models, makes for an ideal environment for creating informal science experiences that encourage and advance girls' science identities. In addition, well thought out exhibit programs and special events can play an important part in igniting and developing girls interest in science and recognition of the importance of science in their lives and in society. Finally, the access that museums and science centers have to the general public, through exhibitions and large-scale events, gives them a role to play in influencing public perceptions of women as scientists.

Ideally, the science experiences designed by museums and science centers should include evaluation and research components. Virtually every topic discussed in this review could benefit from additional research, particularly if that research is rigorously designed to go beyond description of individual programs and examines programs at multiple sites in order to increase generalizability of results.

The international enthusiasm and high levels of activity among museums and science centers working to eradicate gender inequity in areas of STEM-related study and career choices is evident. Dozens of people who were asked to suggest resources, expressed a desire to share their experiences and projects and learn from the experiences and research of other. They also expressed interest in participating in research projects. Institutions and practitioners around the globe are engaged in similar work, and they are eager to be connected. The world stage is set for collaborative work that brings practitioners and researchers together to jointly design programs (interventions), document their effectiveness, and engage in action research that advances both practice and theory.

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