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Chapter

'Making' as a Catalyst for Engaging Young Female Adolescents in STEM Learning

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Abstract

STEM enrichment programs have demonstrated positive impacts on young female adolescents' interest and aptitude in STEM, personal/social-psychological well-being, and educational aspirations. Introducing STEM knowledge and skills in an environment of 'making,' that is, in a setting of hands-on activities, may further enhance adolescent girls' engagement in STEM learning. The maker movement, defined as the convergence of technology and traditional artistry, has generated interest among educators for its potential to nurture STEM learning, including its capacity to engage diverse populations of youths in the making of creative objects through experimentation in science, technology, engineering, and math (i.e., STEM-based making). STEM-based making is a way to support young girls, who often approach making from an esthetic or personal expression perspective, to more fully integrate systems and technologies that advance critical thinking, innovative prototyping, and problem-solving into the making process. Insights are presented as to how STEM-based making designed for young female adolescents—a group that has traditionally had limited access to extracurricular STEM experiences as well as to makerspaces—may foster greater access to, and equity in, STEM learning. The role of universities in facilitating access to and equity in STEM-based making also is addressed.

Keywords: education, STEM, making, adolescent girls, universities

1. Introduction

In the United States, women are significantly underrepresented in the science, technology, engineering and mathematics (STEM) fields, although to a lesser degree than has been the case in the past [1]. A recent survey indicated that although women made up almost half (47%) of the U.S. workforce, only 25% of women held STEM-related jobs [2]. Further, although almost an equal number of women and men hold science and engineering degrees in the US, only a small percentage of women are employed as scientists and engineers [3]. Women and minorities are especially underrepresented in the physical sciences, computer sciences, and engineering [4, 5]. And, although STEM professions grew by 24.4% from 2005 to 2015, women and minorities were not well-represented in this job growth [6].

By 2020, it is projected that U.S. companies will need 1.6 million STEM-skilled employees, with labor market data indicating that core STEM knowledge, skills, and abilities are crucial not only in conventional STEM occupations, but also in a host of other job sectors [5, 7]. The need to develop a balanced and inclusive human resource pool prepared to tackle STEM challenges is further supported by data indicating that, currently, in the US, there are more vacancies in the STEM fields than there are people in the STEM workforce [8, 9]. Thus, it is imperative that initiatives and programs from the government and commercial sectors be designed to specifically recruit and retain women and other underrepresented minorities in order to reduce the gap in the STEM workforce [5]. Establishing a strong and diverse STEM workforce will foster creativity, innovation, and problem-solving skills to ensure America's continued economic growth [10, 11].

In order to successfully address women's underrepresentation in the STEM workforce, it is important to broaden the participation of girls in diverse and exciting STEM education programs, both formal and informal, both in-school and out-of-school, that demonstrate the relevance of STEM learning to everyday life, to educational and professional opportunities, and to solving "real world" problems. Programs designed to heighten interest in STEM learning among adolescent and teenage girls are especially important owing a variety of identified barriers to girls' persistence in STEM education. According to American Association of University Women (AAUW), girls' interest and performance in STEM subjects is greatly affected by stereotypes, gender bias, and loss of confidence regarding their academic achievement in STEM-related courses [12]. Misconceptions regarding STEM and its relevance lead young girls to feel that STEM careers are 'not for them.' Loss of interest and negative attitudes toward STEM careers among girls take root early, during their middle school years, and progress rapidly [13]. Further, middle school girls often perceive STEM-related subjects as uninteresting and difficult [14].

In recent years, educators have made efforts to encourage girls to persist in STEM learning. Evidence suggests that this educational support to girls must start early—in elementary and middle school—rather than in high school [12, 15]. Efforts have been made to identify the forms of educational support that will best nurture girls' STEM interest and learning as well as their confidence to pursue a STEM career. First and foremost, educators must capture girls' attention with an engaging and relevant curriculum and incorporate activities into that curriculum that inspire girls to pursue STEM careers [16]. According to a 2018 study, integrating "real world" problems into STEM curricula can especially be meaningful for girls insomuch as tackling such problems helps to align girls' interests, values, and desires to make an impact through pursuit of a STEM career [17]. Similarly, incorporating hands-on, 'learning and doing' activities may help girls to build critical thinking skills and abilities related to gathering, evaluating, and analyzing evidence to solve today's multifaceted problems [18]. Additionally, exposing girls to positive female role models—especially those who share a background with the young female participants—helps to undermine girls' negative stereotypes about STEM as well as the belief that STEM careers are "not for them" [16]. Immersing girls in STEM learning also may help girls to envision STEM as a realistic part of their academic and professional futures [16].

One approach to immersing girls in STEM learning involves the integration of art, creativity, and design into the learning experience (aka STEAM); or, more specially, learning that embraces the enjoyment and achievement realized from the creation of physical objects—prototypes and/or esthetic and functional items—and that simultaneously demonstrates principles of science, technology, engineering and math [19–21]. This 'product-oriented' approach to learning purposefully embeds creativity into the learning process and positions students as active creators, rather than as passive consumers (Loudon, 2018). Product-oriented learning that marries creativity with advanced technology is the foundation for the modern 'maker' or 'making' movement that is receiving considerable attention across U.S. communities and educational institutions for its potential to foster STEM learning and career opportunities, especially among underrepresented groups such as girls. Although girls may not often associate creativity with STEM occupations or with the ability to make a difference in the world through STEM [17], creativity is integral to many STEM professions. Creativity involves use of the imagination to generate original and valuable ideas or objects, and thereby contributes to complex problem solving in science, technology, engineering and math [22]. An empirical study exploring the relationship between problem-solving, creativity, and interest in STEM revealed that girls' interest in problem-solving was a predictor of their interest in all four STEM subject areas and that girls' interest in creativity was a positive predictor their interest in computers and engineering [11]. Further illustrating the importance of creativity in STEM professions, the World Economic Forum's [23] job report identified analytical thinking, innovation, active learning, and proficiency in new technologies (design and programming) as well as 'human' skills, such as creativity, originality and initiative, critical thinking, persuasion and negotiation and complex problem-solving as important workplace skills that will retain or increase their value by 2022.

With this chapter, we address the potential of making to serve as a catalyst for engaging young female adolescents in STEM learning. More specifically, we explore how STEM-based making may encourage young female adolescents, who often approach making from an esthetic or personal expression perspective [24], to more fully embrace and integrate systems and technologies that foster creative and critical thinking, innovative prototyping, and problem-solving into the learning process. Additionally, we present insights as to how STEM-based making designed specifically for young female adolescents—a group that has traditionally had limited access to extracurricular STEM experiences as well as to makerspaces owing to age, gender, and socioeconomic status [25, 26]—may foster greater access to, and equity in, STEM learning. We conclude by exploring the role of colleges or universities in facilitating access to and equity in STEM-based making through an in-depth look at three STEM education programs that were established by faculty at U.S. universities specifically to provide adolescent girls the opportunity to engage in experiential STEM learning in resource-rich environments.

2. Engaging young female adolescents in STEM learning

2.1 Making and makerspaces

The maker movement, defined as the convergence of technology and traditional artistry, is generally associated with informal learning that encourages exploration, discovery, and understanding [27]. Making may take many forms and encompasses a variety of activities, such as design thinking, building, testing, and modifying, that are oriented toward the creation of a physical object. Making fosters collaboration and experimentation, and it involves a trial and error approach to problem-solving, wherein failure is recognized as positive part of the learning experience [28]. Making introduces learners to a variety of disciplines and encourages them to assume multiple roles, such as designer, computer scientist, material expert, mathematician, and inventor, and to utilize diverse experiences, knowledge, methods, and skills to identify innovative solutions to simple and challenging problems [28]. It also presents opportunity for more diverse teaching roles, in the form of mentoring and peer teaching, than are typically available in a traditional school setting [29, 30].

The maker movement is grounded in constructionism and constructivism theories, which posit that creation-based experiences are foundational to learning [31, 32]. In particular, constructionist and constructivism principles propose that learning is best supported when students engage with tools and technologies to make physical objects through authentic, hands-on experiences that incorporate guided, peer-supported, collaborative processes [31, 32]. Hands-on, collaborative experiences—that is, the bringing of people together for the exchange of ideas—help students integrate existing and new knowledge and foster their problem-solving skills. These perspectives also recognize the social aspects of learning, and in particular, the potential for students to learn through "tinkering," an iterative, creative, and playful form of exploration and experimentation with technologies, tools, and materials [33]. In prior work, both peer-supported and tinkering experiences have been linked to positive learning outcomes [34]. Similarly, the hands-on, collaborative, playful, technology-driven qualities of the constructionist "learning by doing" approach provide an apt platform for the introduction and mastery of STEM educational competencies [35]. Further, as world view theory proposes, situating STEM education in the context of students' existing interests, everyday life, or ideas that students find to be significant can be a meaningful way to support STEM learning across diverse disciplines [36].

Today's maker movement is supported by new digital fabrication technologies (i.e., computer aided design + computer aided manufacturing, CAD/CAM) that play a valuable role in prototyping and product development and, in turn, drive innovation [37, 38]. Digital fabrication technologies, or 'digital tools' are one of three components necessary to realize to full potential of making in education; the other two being 'community infrastructure' and a 'maker mindset' [28]. Digital tools include physical tools that shape materials into objects, such as 3D printers, digital embroidery machines, and laser cutters as well as logic tools or programmable devices (i.e., microcontrollers) that process input from sensors, switches, and internet data to control output devices, such as LEDS. The growing affordability of these tools offers the potential for increased accessibility to making across the population [28]. The second component of the maker movement, community infrastructure, which includes both online and offline access to information, inspiration, and mentoring, is especially critical to engaging youth in making. Learning or making communities have the capacity to foster interest, identity, and learning among youth; when youth are interested in a subject or activity and when that subject or activity aligns with their identity and when they feel connected to a community founded upon shared interest in that subject or activity, there is tremendous opportunity for learning [39]. The third component, maker mindset, refers to the values, beliefs, and dispositions that characterize individual engagement in a maker community.

Drawing from prior work, Martin [28] presented four elements of the maker mindset required to harness the full value of making in education. The first element is experimental play, which implies that making is viewed as a fun, enjoyable activity or pleasant experience in an environment that encourages experimentation and learning. The second element is the asset-oriented or growth-oriented nature of making, which embodies a free-choice approach to 'what' to make and encourages the belief that anyone can learn to make. The third element, failure-positive, fosters understanding of the role that failure plays in making and learning. This is the recognition that failure is important to the creative process because it necessitates more critical thinking or tinkering to achieve envisioned solutions to simple and challenging problems. The fourth element is collaboration, which involves a willingness to share ideas and information with others, to assist and support others in their making endeavors, and to connect with others through the activity of making [40].

Makerspaces are defined as places where 'likeminded' individuals come together to exchange ideas, learn skills, share knowledge, and utilize technology and tools to create objects [41] and represent the collective manifestation of digital fabrication technologies, community infrastructure, and a maker mindset. Makerspaces emphasize hands-on discovery in an increasingly automated world, and although they vary considerably with respect to the scope and sophistication of the technology and tools available, well-equipped spaces often include computers as well as design and engineering software; 3-D printers; audio and video capturing/editing tools; wood, metal, and glass making equipment; digital textile printers, embroidery, and knitting machines; sewing machines and/or fabric welders; and/or commercial cooking equipment. Makerspaces typically require partnerships among varied stakeholders, including makers—artists and scientists, community members and organizations, government representatives, educators, digital technology and equipment companies, and others—to inform best practices for the creation of well-equipped makerspaces that ensure equity-oriented use, exploration, and learning as well as to meet the financial cost of creating such spaces. Additionally, makerspaces that embody the four elements of the maker mindset—experimental play, free choice, positive failure, and collaboration—are most likely to realize the full value of making in education [28]. Makerspaces may support a maker mindset by providing an array of technologies, maximizing open, unstructured use time, offering a variety of free or inexpensive materials, and employing experts or mentors with diverse backgrounds and varied making skills.

2.2 Equity in STEM learning through access to making and makerspaces

Making has generated interest among K-12 educators for its potential to foster STEM learning, including its capacity to engage youth, in the hands-on creation of esthetically-pleasing objects informed through experimentation in science, technology, engineering, and math (i.e., STEM-based making). In particular, making has the potential to engage youth who may not self-identify as 'good at science,' in STEM learning through the creation of innovative and personally meaning objects (i.e., product-oriented learning) [41]. Further, when STEM knowledge and skills are introduced in an environment of 'making' in a setting of hands-on, art, craft, or design activities, there is evidence that female adolescents, who often approach making from an esthetic or personal expression perspective, may become more engaged in STEM learning [24, 42].

The benefits of STEM learning provided within extracurricular and informal, open learning environments, ranging from after school clubs to summer programs, is well documented (see [43]). Findings from the Harvard Family Research project [44] revealed that extracurricular STEM programs have the capacity to improve attitudes toward school, interest and aptitude in STEM, personal/social-psychological well-being, and educational aspirations, particularly among adolescents from lower-income families. Informal, out-of-school environments typically allow for more independence, creativity, and personal inquiry, all of which have been shown to support STEM learning [43]. Further, participation in STEM clubs and activities outside of school helps boost girls' confidence to pursue a STEM-related career [28]. Kafai et al. [20] exposed seventh and eighth grade Native American students to STEM learning in a summer camp environment, where students engaged in the ethnographic study of electronic textiles to foster learning and participation in computer programming and engineering. After making their own customized, culturally-inspired, electronic textiles using the LilyPad Arduino, the students perceived computer programming to be more relevant to their identities, their daily lives, and their career choices. The students also reported greater engagement in the learning process and greater confidence in their computer programming skills [20]. Similarly, Thuneberg et al. [21] engaged 12–13 year old students in a product-oriented learning workshop for an math and art exhibition that combined creativity, mathematics, and engineering in the making of structures and creatures that embodied the fusion of art and technology and depicted curiosity, imagination, and play. Findings revealed that that the lowest achievers liked learning math through hands-on activities related to the exhibition, and preferred it over learning math in school. For girls, the situational motivation (i.e., the esthetic aspect of the exhibition) was strongly related to attitudes toward technology and sciences, the importance of math, and future educational plans. Another example of an out-of-school, hands-on learning module, combing experimentation and creative modeling to visual DNA-structure, examined cognitive achievement among 9th grade students [45]. The researchers observed positive correlations between cognitive achievement and model quality and cognitive achievement and creativity among female participants, concluding that creative hands-on modeling appears to support girls' science learning.

The maker movement is often acknowledged for its capacity to offer democratic access to advanced technology that previously was only accessible to experts or to privileged individuals; primarily affluent, well-educated, white males [26, 46, 47]. However, the full capacity of making to foster inclusivity, that is, to engage women, youth, ethnic minorities, LGBTQ+ individuals, persons with disabilities, and other underserved communities/populations in STEM learning, has not yet been realized owing to the limited number of makerspaces and making programs that prioritize access for underrepresented groups [46]. A clear divide remains between those with access to well-equipped makerspaces that offer advanced technology (e.g., computers, software, virtual reality), modern machinery (e.g., digital printers, 3-D printers, laser cutters), and expert technicians, mentors, and peer teachers and those without access to makerspaces, which remains a challenging obstacle to equity in STEM learning [42]. Makerspaces do not adequately address barriers to entry (e.g., cost, location) or the exclusionary practices (e.g., membership, enrollment) that limit engagement in making and STEM learning among members of the broader population [46].

Dawson [26] notes that it is critical to establish safe and welcoming learning/making spaces—where all experiences and knowledge are respected and valued—for youth, women, and/or people of minority ethnic backgrounds. Access to maker spaces is often constrained by structural inequalities, yet, such spaces have the capacity to disrupt notions about *who* can engage in STEM learning/making and to provide opportunities for social justice and thereby increase diversity in learning [20, 26]. Ryoo and Calabrese Barton [41] contend that although it is important to continue to address access and opportunity, it is especially important to examine the power structures that shape access. This includes the types of making that are valued, as well as how making and makerspaces address the needs and rights of youth from nondominant communities in ways that are equitable for all youth, especially for youth of color and girls who are historically underrepresented in STEM. Thus, making experiences and maker spaces that specifically account for the needs, rights, and interests of young female adolescents, a group that has traditionally experience limited access to extracurricular STEM programs as well as to makerspaces owing to age, gender, and socioeconomic status [25, 26, 46], may help to foster greater equity in STEM learning.

2.3 University STEM programs for girls: facilitating access and equity in STEM learning

Universities and colleges may be especially well positioned to facilitate adolescent girls' access to equity in STEM-based making and learning. Central to today's university/college campus are well-educated, same gender, faculty and student role models, facilities (e.g., computer and science laboratories) that support higher-order STEM learning, and, more recently, the development of well-equipped makerspaces designed purposefully to engage students in creative and innovative exploration. Equally important is the commitment among today's universities and college to better serve all members of society by demonstrating principles of inclusion, diversity, and social justice, which includes the development and delivery of educational programs for middle school and high school students that are specifically targeted toward underrepresented groups, including members of the Native American and the Latinx communities. Masters et al. [48] have argued, however, that in order for making to be truly inclusive, diverse, and liberatory, the design and operation of makerspaces must extend beyond the domain of education and universities to also involve community leaders and support community goals. Calabrese Barton et al. [25] also considered the role of youth in the purposeful co-design of making opportunities to engage underrepresented youth in STEM. Partnerships between educators, community members, and youth may, in fact, offer the greatest promise for democratic access to makerspaces through the intentional removal of barriers, and may, in turn, offer the greatest potential to achieve equity in STEM learning.

The widespread acknowledgment of the benefits that can accrue from offering girls early, positive, STEM socialization experiences has prompted the development of numerous informal, out-of-school STEM education programs specifically targeting the needs of girls (see [49], for a review). Many of these programs have been developed and facilitated by university faculty and students. Frequently, such programs are offered on university campuses, providing participants access to rich learning resources and immersing them within the stimulating context of higher education. Programming has been offered in diverse formats, ranging from after-school clubs (e.g., Building Girls Up in Science), BUGS [50] to one-day workshops (e.g., Talented At-Risk Girls: Encouragement and Training for Sophomores), TARGETS [51] to nonresidential and residential summer camps (e.g., Fashion FUNdamentals [19]), Camp Reach [52]. Some programs, such as Females Excelling More in Math, Engineering, and Science (FEMMES) have included a mix of program formats to achieve their mission [53–55]. Programs also have targeted girls of varied ages, ranging from elementary school students to undergraduate students, with one unique program—Georgia Computes! [56]—addressing the needs of female students (and underrepresented students of color) throughout the entire educational pipeline, from elementary school through the university experience.

In this section, we highlight three innovative university STEM programs—FEMMES, Fashion FUNdamentals, and Digital Youth Divas—developed to specifically facilitate access and equity in STEM learning among young girls. These programs focus upon the needs of girls in the upper elementary (FEMMES) and middle school years (Fashion FUNdamentals, Digital Youth Divas). As is true of many programs developed for elementary and middle school students, each of these programs aims to provide girls positive experiences with STEM, to maintain and promote girls' interest in STEM, to enhance girls' confidence in STEM, and, ultimately, to increase women's representation within STEM fields in higher education and within STEM careers upon graduation (cf, [49]). We chose to feature the selected programs because participants have evidenced positive outcomes and because these programs integrate characteristics that have been identified as integral to a successful STEM education program for girls, including (a) the creation of an engaging and relevant curriculum that incorporates hands-on/'learning and doing' activities, (b) the integration of 'real-world' activities that inspire career exploration, (c) exposure to positive female role models, and (d) opportunities for immersion in STEM environments [16–18]. Importantly, in differing ways, these programs also incorporate selected components identified by Martin [28] as essential in promoting the full potential of making in education.

2.3.1 Females excelling in math, engineering, and science (FEMMES)

Founded in 2006 at Duke University, FEMMES is a student-managed outreach organization that actively engages girls in STEM fields through experiential activities and mentoring from female university faculty and students. Most FEMMES program components target underserved girls in 4th through 6th grades. Since its inception, FEMMES has expanded to include chapters at multiple universities (e.g., University of Michigan, UNC Chapel Hill, and the University of Chicago) as well as diverse program components, including a one-day 'capstone' experience, a 6-week after-school program, a Saturday program that parallels the content of the after-school program, a summer camp, a hackathon (designed for female-identifying students enrolled in grades 9–12) [54], and a mentorship program (FEMMESConnect) that allows FEMMES participants to build upon their prior involvement in the FEMMES programming. Here, we focus upon selected components of the FEMMES program that have been offered in collaboration with Duke University and that have been formally evaluated within the research literature: (a) the capstone experience [55] and (b) the after-school program [53].

The capstone component of FEMMES is a free, annual, one-day STEM education mentoring program attended by more than 200 4th–6th grade girls enrolled in Durham, North Carolina elementary schools. The event is held in the science and engineering facilities on the Duke University campus and opens with a keynote address. Interactive sessions follow the keynote address and involve participants in small-group, hands-on activities facilitated by university faculty and female student counselors/mentors. The activities reflect the expertise of the female faculty who guide them and focus on conventional STEM topics such as biology, biomedical and electrical engineering, chemistry, computer science, environmental science, math, and statistics. Activities are designed to be engaging and "fun." For instance, in a pharmacology activity, participants consider "pharmacology as sleuths," and in a computer science activity, participants create a 3D interactive story [54, 55].

An assessment of the effect of participation in the 2008 and 2009 capstone events revealed increases in 4th–6th grade girls' interest, knowledge, and confidence in math, science, and engineering from the beginning to the end of the FEMMES program. With the exception of a slight loss of interest in science and engineering, these gains persisted over the next 3 months, suggesting that the combination of hands-on activities and mentorship from female faculty and students may be valuable in inspiring young girls' STEM achievement [55].

The FEMMES after-school program is a free, 6 week STEM education opportunity for 4th–6th grade girls attending selected, underserved elementary schools in Durham, North Carolina. The program curriculum addresses a range of science topics (e.g., biology, chemistry, physics, earth science, and engineering) through hands-on, problem-based approaches that encourage the development of critical, analytical, and teamwork skills. Example activities include a chemistry lesson in which students make ice-cream to understand how salt decreases the freezing point of water and a bridge-building activity in which students explore basic concepts in physics and structural engineering. Programming takes place once per week (1 h per session) at the elementary schools, where girls work in small groups that are facilitated by female undergraduate and graduate student mentors who have been trained to provide encouragement and support to participants and to present material in a manner that engenders enthusiasm in learners. In 2009, the after-school program served 100 students, with a student-mentor ratio of 4:1 [53, 54].

A (combined) evaluation of the 2009 and 2010 FEMMES after-school program offerings revealed that, at the conclusion of the program, girls demonstrated increases in science, interest in engineering, knowledge in science, confidence in math, and confidence in science. Although analyses did not specifically explore aspects of the program most valued by participants, it is possible that the overall positive impact of participation could be linked to various aspects of the program, including the interactions with positive female role models/mentors, the integration of open-ended activities, and/or the incorporation of cooperative learning strategies [54, 55].

2.3.2 Fashion FUNdamentals

Founded in 2015 at Colorado State University, Fashion FUNdamentals is a STEM enrichment program that leverages middle school girls' 'passion for fashion' to build their STEM interest and skills and to foster their self-esteem. The program is grounded in world view theory and research on the maker movement, both of which support the value of connecting STEM learning to girls' existing interests and experiences, including experiential, open-ended, art, design, and craft activities [28, 39, 42, 57]. Fashion FUNdamentals is offered as a two-week summer program (M-F, 9 am–5 pm) that targets underserved girls entering 6th, 7th, and 8th grades; the program is offered free of charge to girls who participate in their schools' free and reduced lunch programs. The program is delivered primarily by female faculty and students on the Colorado State University campus and makes use of the university's state-the-art equipment (e.g., body and foot scanners, digital textile and 3-D printers) and laboratories [19, 58, 59]. To date, a total of 146 girls have been served by the program. In years with larger enrollments, girls are divided into groups of 15–24 and rotate through the program with their cohort.

The Fashion FUNdamentals curriculum includes both technical and social programming components, thereby addressing diverse educational needs of participants. Technical programming is designed to enhance girls' STEM interest and aptitude through engagement in hands-on activities that require application of STEM knowledge to develop solutions to 'real world' problems within the global fashion industry. The development of technical programming curriculum is guided by Colorado Academic Standards in math and science. Technical programming units address fiber/textile science, digital textile design, apparel construction/engineering, apparel costing and pricing, merchandising assortment planning, historic textiles, and wearable technology. Example technical programming activities include (a) using optical microscopes to examine various fibers, exploring synthetic fiber formation through spinning techniques, and dyeing and comparing the qualities of dyes on different fabrics (fiber science unit), (b) employing computer-aided design and digital textile printing technologies to create and print original textile designs (digital textile printing unit), and (c) employing 3-D body scanning technology to measure human body dimensions to calculate critical measurements for garment construction (apparel engineering unit). Because the program aims to foster creativity, girls are provided as much flexibility as possible in shaping what they make (e.g., in developing their textile prints and garment designs). Social programming focuses upon issues of social and psychological concern among middle school girls and is designed to support participants' self-esteem, and thus, their academic performance [60]. Social programming units address anti-bullying, body image/media literacy, internet safety, nutrition, and physical activity (e.g., creative movement, swimming, rock climbing). Example social programming activities include (a) analyzing the meanings and social consequences of messages included in teen fashion magazines and creating t-shirts featuring body positive messages (body image/media literacy unit) and (b) planning, preparing, enjoying, and analyzing the nutritional content of a healthy snack (nutrition unit) [19, 58, 59].

Outcomes of participating in Fashion FUNdamentals have been assessed through the collection of both quantitative and qualitative data. Analyses of quantitative data collected from girls who participated in the 2015 offering of Fashion FUNdamentals demonstrated three key outcomes of girls' engagement in the program: (a) girls reported higher levels of self-esteem at the end of the program than at the beginning, (b) girls reported higher levels of self-efficacy in math and science at the end of the program than at the beginning, and (c) girls who perceived math and science as pertinent to or useful in everyday life were more prone to report higher interest in STEM at the conclusion of the program than at the beginning [19, 58, 59]. Key findings from qualitative analyses from the 2015–2017 offerings of Fashion FUNdamentals further enrich understanding of these quantitative results, revealing that participation in the program (a) expanded girls' appreciation for the value of STEM and the relevance of STEM to everyday life contexts, (b) moved girls toward increased self-acceptance, self-confidence, and self-esteem, (c) improved girls' problem-solving abilities and courage to learn by 'making mistakes,' and (d) developed a foundation for girls' future academic and career aspirations. Notably, immersing underserved girls in interactions with female faculty members, students, and STEM professionals in a university setting exposed girls to new ways of thinking about the role of STEM in diverse disciplines and careers and inspired them to attain a college degree and (possibly) to pursue a career in a conventional or nonconventional STEM field [59]. Taken together, then, quantitative and qualitative findings suggest that invoking a lens of fashion to explore the STEM disciplines can promote girls' academic and personal development [19, 58, 59].

2.3.3 Digital Youth Divas

Founded in 2013 and offered through the Digital Youth Network at DePaul University [61, 62], Digital Youth Divas is a hybrid, online and face-to-face STEM program designed particularly to address the needs of nondominant middle school girls who have not previously expressed an interest in the STEM disciplines [63, 64]. The program engages girls from underrepresented Chicago communities in design-focused engineering and computer sciences activities. Throughout the program, emphasis is placed upon immersing participants in narratives with nonstereotypical storylines, providing participants opportunities for interactions with racially-diverse female peers and mentors, and helping participants to call into question gender and racial stereotypes [63, 64]. Like Fashion FUNdamentals, Digital Youth Divas aims to bridge girls' existing interests with the STEM disciplines. Specifically, through their participation in Digital Youth Divas, girls are encouraged to develop STEM identities by interacting in face-to-face and online spaces to design, engineer, and re-imagine everyday objects (e.g., jewelry, fashion accessories, music) and activities (e.g., dancing, chatting with friends) using strategies of cooperative learning, critique, circuitry, coding, and making [61, 63, 64].

Digital Youth Divas has been offered in several formats (e.g., as an afterschool program, a one-week spring break program, and a two-week summer program), all of which incorporate four interrelated program components: (a) design projects, (b) narrative stories, (c) an online social network platform, and (d) a community of female and racially-diverse peers and mentors [61, 63]. Design projects are specifically developed to encourage interest among nondominant girls by engaging them in the construction of creative products (e.g., e-fashion, basic programming projects). Narrative stories introduce participants to various STEM/design-thinking challenges that prompt them to develop creative solutions through team-work; storylines deconstruct dominant stereotypes about race and gender. Within the online social network, participants engage with the program curriculum and the narrative stories, as well with one another, sharing their work and providing feedback to each other. Interactions within this context also allow participants the opportunity to construct their personal narratives and to 'try on' various STEM-related identities. Thus, the online social network represents a unique STEM environment that also supports girls' social and personal development. Finally, a community of diverse female peers and mentors is integral to all components of the Digital Youth Divas participant experience. Face-to-face female mentors share cultural background connections with participants and have completed program training but are not engineers by trade, whereas online mentors and program leads possess have formal expertise in engineering or computing as well as training specific to the program [61, 63, 64].

Since 2013, over 300 girls have participated in varied Digital Youth Divas program offerings [61], with evaluations suggesting similar participant outcomes across program formats [63]. Here, we summarize a qualitative evaluation of the pilot offering of the Digital Youth Divas after-school program [64] and a quantitative evaluation of a two-week summer program offering of the program on the DePaul campus [63]. The afterschool program was offered to a total of 17 girls at two public charter schools once/week for the spring semester. Observations of the learning sessions and in-depth interviews with participants revealed that, as result of their participation in Digital Youth Divas, girls experienced a sense of empowerment through the design/making activities. Additionally, findings suggested that the project narratives encouraged participants to persist in STEM challenges, lending a sense of authenticity to their efforts and fueling their interest in STEM learning. Girls invoked the narratives as platforms to dialog about diverse stereotypes as well as to envision varied (STEM, gender) identities for themselves [64]. The two-week summer offering of Digital Youth Divas was provided to 37 girls at a cost of $40 to participants and ran M-F from 9 am–3 pm. A comparison of assessments completed at the beginning and the end of the program revealed that participation in Digital Youth Divas positively influenced girls' understanding of STEM concepts as well as their confidence to take part in STEM activities. Engagement in the program also expanded girls' perceptions of 'who' ought to pursue STEM careers (e.g., to include people who are artistic) (cf, [16]). As such, findings provide evidence that a STEM program grounded in a narrative-based curriculum and committed to challenging stereotypes can support growth in nondominant girls' STEM interest, knowledge, and confidence, as well as their beliefs about inclusivity in STEM [63].

2.3.4 Connections to making

As noted, in varied ways, each of the programs highlighted here harnesses the potential value of making as an educational framework to support girls' learning in the STEM disciplines. Specifically, to varying extents and in differing ways, these programs incorporate components of making and the maker movement identified by Martin [28] as fruitful for supporting learning, including (elements of) the maker mindset, digital tools, and community infrastructure [28]. Most notably, at the core of each program is the framing of STEM learning as experimental play. For instance, girls are invited to be 'pharmacology sleuths,' to make ice-cream, to design their own textile prints, to create fashion accessories and products, and to engage with interactive stories, all while reinforcing their STEM skills. Here, then, STEM learning is cast as experiential and enjoyable because it is designed to be engaging and to build upon girls' interests and identities and/or to connect STEM learning to everyday, real-life contexts [28, 36, 42]. Fashion FUNdamentals and Digital Youth Divas, in particular, adapt the lens of making from an esthetic and personal expression perspective to entice girls to engage with STEM learning [24, 42].

As they 'make,' transforming materials into finished objects, participants in the featured programs employ varied digital tools, such as digital textile printers, body and foot scanners, and LEDs [28]. Open-ended activities afford girls 'free choice' in decisions about what form the objects they create will take—whether those objects be a bridge, an interactive story, or a craft/textile/fashion product [28]. Providing girls this sort of 'room to roam' creatively seems to build girls' self-confidence and sense of empowerment as makers and as STEM learners [19, 28, 53, 55, 58, 64]. Both individual and collaborative projects are undertaken in the featured programs, providing girls opportunities to exercise their individual agency as makers as well as to build their skills as cooperative learners and problem-solvers [28]. Incorporating collaborative, hands-on approaches to 'learning through doing' seems to promote an openness to learning through trial and error among participants in Fashion FUNdamentals [59]. This is of note, as STEM educators advise that learning through making mistakes will help the next generation 'test new ideas in messier ways' as they enter the digital age [65]. Finally, and importantly, central to the scaffolding of each of the highlighted programs is a commitment to (a) providing girls positive female mentors and role models in STEM (who, in the case of Digital Youth Divas, come from backgrounds similar to those of the participants) and (b) offering girls opportunities to connect with one another in face-to-face and/or digital formats, sometimes in contexts that extend beyond the duration of the program (as in the case of FEMMESConnect) [16, 28, 54].

3. Conclusion

As an active learning strategy—or a way of *learning by doing*—making encompasses a wide range of activities and draws from diverse disciplines. Its connections to computer programming, creativity, design, and engineering, in particular, position making as a unique and valuable vehicle through which to ignite girls' interest in STEM, build their STEM identities, and foster their confidence to pursue STEM education and careers [20, 21, 64]. However, access to making programs and makerspaces remains a significant challenge in leveraging the potential of making to stimulate girls' STEM learning. As previously noted, access to maker spaces is often constrained by structural inequalities, and especially for youth of color and young female adolescents, groups that have conventionally experienced limited access to extracurricular STEM educational opportunities, as well [20, 25, 26, 46]. Given their long-standing commitment to principles of inclusion, equity, and diversity as well as their resource rich environment (e.g., people, technologies, facilities), universities are an important stakeholder in expanding access to STEM education to all members of their community, including girls, through the development of outreach programs that incorporate components of making. As demonstrated in our overview, university STEM programs developed with the aim of facilitating access and equity in STEM learning among young girls may take diverse forms, may emphasize either conventional or unconventional STEM disciplines, and may incorporate elements of making in varied and unique ways. Key to the success of such programs in kindling girls' STEM interest, confidence, and identities seems to be incorporating activities (a) that leverage girls' existing interests, (b) that provide girls the freedom to define and express the self in creative ways, and (c) that offer girls opportunities to have "enjoyable" and "fun" experiences.

Although the girls enrolled in the university STEM programs reviewed in this chapter have evidenced positive outcomes, these and other similar programs are challenged to provide repeated "touch points" of contact with participants. To some degree, the capacity to build repeated touch points within a university setting is constrained by several factors, including (a) the time that faculty and student college student mentors can dedicate to such programming owing to their primary educational obligations and responsibilities; (b) the availability of university facilities, including makerspaces, equipment, and technologies; and (c) the availability of funding to support program development and operations.

However, in order to encourage girls to pursue STEM learning and STEM careers, continuous social and educational support through the K-12 years is needed [10]. A stakeholder approach that brings together university and K-12 educators—as well as other community groups such as students, parents, local government agencies, and local industry, particularly in the technology sector—may be particularly effective in addressing this challenge. Such an approach would enable varied stakeholders to collaborate in a joint effort to reach girls at multiple junctures across the K-12 educational pipeline by sharing expertise and resources across stakeholders (e.g., universities' sciences laboratories and makerspaces and K-12's educators' knowledge, skills, and time). For instance, presently, through Colorado State University's summer camp offerings, adolescent girls are able to participate in different STEM-based making programs such as Fashion FUNdamentals at the middle school level, Women in Construction Management at the early high school level, and SWiFT STEM camp (a computer science and coding program) at the upper high school level. If a coordinated effort were made to adopt a stakeholder approach to bringing together the directors of these programs with K-12 educators in the local school district, work could be undertaken to ensure bridge-building between university program content and the K-12 curricula, facilitating the dual aim of engendering within girls a passion for STEM learning through making and creating repeated touchpoints to support girls' mastery of key STEM concepts.

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