Untapped Potential

Makerspace as Conduit for Talent Development

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Abstract

This article explores how makerspaces, a quickly growing development in schools, museums, public libraries, and other community spaces, may act as a conduit for talent identification and development for all students. The purpose of this paper is to provide an exploration of recent questions asked within gifted and talented scholarship in alignment with current research on makerspaces and maker style learning to suggest that the study of makerspaces may illuminate novel opportunities and new strategies for identifying and nurturing gifts and talents in all students to solve current and future societal problems.

Keywords: makerspace, talent development, talent identification, giftedness, creativity, best practices, inquiry learning, problem-based learning, society

Introduction

> *Talents and skills are ubiquitous. Education should be designed to reveal the talents and skills of every child.*
>
> —Pamela Cantor (2021, p. 15)

Cantor (2021) is not the first to recognize that schools are not designed to reveal the gifts and talents of all students. For decades scholars have called attention to the shortsightedness of traditional schooling. Among others, Treffinger and Feldhusen (1996) point out that schools should be designed to give every student the opportunities and tools to develop to their own best ability; that utilizing a talent orientation rather than a giftedness lens "represents a new educational orientation that is concerned with the development of talents at all levels of ability, not just the highest or most precocious levels" (p.182).

Gifted and talented education in the United States has a long tradition of identifying students based on intellectual ability, typically using an achievement or aptitude test, to provide learners with opportunities to achieve more, to reach a higher level of giftedness. It has been suggested that traditional identification of gifted students misses a large number of those who do not perform well on standardized assessments, including some minorities (Andreadis & Quinn, 2017; Coronado & Lewis, 2017; Hodges et al., 2018). Despite decades of scholars calling attention to the weaknesses in identification of gifted and talented students, and proposals of alternative practices (Bloom & Sosniak, 1981; Gardner, 1983, 1995; Renzulli, 2012; Sternberg, 1984, 2015; Subotnik & Coleman, 1996; Treffinger & Feldhusen, 1996). IQ scores and academic achievement are still the most frequently used criterion for determining gifted and talented status in the United States public school system, and programs offered still focus on academic domains (National Association for Gifted Children & The Council of State Directors of Programs for the Gifted, 2015). As Dai and Renzulli (2008) explain, "a gifted program that only identifies high achievers in a conventional manner (relying on standardized achievement or aptitude tests) as gifted is destined to miss a big chunk of the innovative side of gifted potential" (p. 12). This may be critical as we move deeper into the 21st century.

Subotnik, Olszewski-Kubilius, & Worrell (2011) call attention to the importance of studying giftedness and talent development to address societal needs such as generating innovative products, services, and ideas as solutions for current and future problems related to the environment, economic, and social needs. Psychosocial skills development may be one of the most important focuses for talent development in the 21st century (Olszewski-Kubilius et al., 2016)including climate change and economic inequality. In this context, the development of talented individuals who can tackle these problems is most important. In this article, the authors discuss the implications of 21st-century challenges for the development of talent based on their megamodel (Subotnik, Olszewski-Kubilius, & Worrell, 2011. With the need for identification of gifts and talents, but the potential of missing the very talents needed in the 21st century, how can educators identify and cultivate talents in all students? One possible solution may be makerspaces.

First, makerspaces provide opportunities for all students to engage in a wide variety of activities and domains learners may not typically explore on their own or in a school setting, so they may be one way to *identify* students with untapped gifts and talents. Second, makerspaces provide opportunities for learners to practice in new domains, as well as an environment that encourages psychosocial growth, and may support the *development* of talents.

This article is organized into four sections. The first section provides a brief review of literature on giftedness and talent development. The second section presents an explanation of what a makerspace is, what may happen in a makerspace, and some of the empirically identified outcomes from participating in makerspaces. The third section explores how makerspaces and gifted and talented education intersect. The final section explores and how this intersection may be an opportunity for further research.

Gifted and Talented Identification and Development

Recent models and theories of giftedness and talent development have embraced gifts and talents as multifaceted, with less focus on cognitive or academic abilities alone, and increased attention to other areas including creativity (innovation) and problem solving. Current theory recognizes that innate ability (nature) is only one factor in the development of gifts and talents, and that environment (nurture), as well as psychosocial factors play a role (Barbot et al., 2015; Barron, 2006; Bronfenbrenner & Ceci, 1994; Ceci et al., 2016; Dai, 2017; Stoeger et al., 2017; Subotnik et al., 2011). Scholars Subotnik, Olszewski-Kubilius & Worrell define giftedness and talents as follows:

> Giftedness is the manifestation of performance or production that is clearly at the upper end of the distribution in a talent domain even relative to that of other high-functioning individuals in that domain. Further, giftedness can be viewed as developmental, in that in the beginning stages, potential is the key variable; in later stages, achievement is the measure of giftedness; and in fully developed talents, eminence is the basis on which this label is granted. Psychosocial variables play an essential role in the manifestation of giftedness at every developmental stage. Both cognitive and psychosocial variables are malleable and need to be deliberately cultivated. (2011, p. 7)

Identification

Although some state and local educational agencies recognize domains of gifts and talents such as creativity, performing arts, and leadership, it appears that a majority of educational institutions in the United States still utilize ability and achievement tests to identify gifted and talented students (National Association for Gifted Children & The Council of State Directors of Programs for the Gifted, 2015). There is a high probability that using such measures for identification miss many students who could benefit from gifted and talent development programming. In fact, a recent meta-analysis of identification practices (Hodges et al., 2018) indicates that there are still disparities in the identification of gifted and talented students among underrepresented (Black, Hispanic, and Native American) and represented (Asian and White American) populations, with variation in these disparities based on geographic region of the United States and the identification methods used. Included in the meta-analysis were identification practices such as portfolios and checklists, as well as tests that focus on problem solving, reasoning ability, and observation skills such as the RAVEN test and the Naglieri Nonverbal Abilities Test (NNAT), as well as the Cognitive Abilities Test (CogAT) (Hodges et al., 2018).

One additional model of identification worthy of consideration is Sternberg's (2015) augmented model of successful intelligence, also known as WICS (wisdom, intelligence, and creativity, synthesized), which identifies intelligence based on creative, analytical, practical, and wisdom-based skills to determine the potential for later success because, as Sternberg explains:

> In almost any life pursuit, people need to think (a) creatively to generate new and valuable ideas, (b) analytically to judge whether their ideas and the ideas of others are worthwhile; and (c) practically to implement their ideas and to convince others of the value of those ideas. People also need (d) wisdom to help to ensure that their skills are utilized to achieve a common good that balances their own (intrapersonal) interests with other people's (interpersonal) and institutional (extrapersonal) interests over the long term, not just the short term. (Sternberg, 2015, p. 77)

While domain general abilities like problem solving, analytic capacity, and creativity are accounted for in many models of identification, the domain specific talents necessary to address 21st century needs are not. Domain specific talent needs of today and for the future are vastly different from those in previous centuries, or even previous decades. Olszewski-Kubilius, Subotnik, & Worrell (2016) predict a growth in the need for talent in domains including "entrepreneurship, technology (robotics, artificial intelligence, nanotechnology), the environment (clean energy), and health care (genomics)" (p.142) to address societal needs. Over-reliance on existing ability assessments are likely to miss talents in new and emerging domains because it is difficult to identify talent in a new domain, and impossible when a domain does not exist yet.

Development

In a review of existing theories and models of giftedness and talent development, Subotnik, Olszewski-Kubilius & Worrell (2011) developed a mega-model of talent development which proposes that there are two sets of factors that enhance talent development – psychosocial, and external and chance. Included in the psychosocial factors are optimal motivation, opportunities taken, productive mindsets, developed psychological strength, and developed social skills. External and chance factors include opportunities, financial resources, and social and cultural capital (Subotnik et al., 2011).

Despite a multitude of theories about how talents develop (and the agreement amongst most scholars that gifts and talents extend beyond academic prowess) in practice, services for gifted students are often still focused on academics, with only limited focus on other domains. The majority of schools surveyed in the *National Association for Gifted Children State of the States in Gifted Education Report* (2015) indicate that programs and services are most often offered related to gifts in general academic areas, visual/performing arts, intellect, specific academic areas, creativity and leadership—though none of the constructs are clearly defined in the report. Further, the report indicates that the service delivery models rely most often on academic interventions such as self-contained classrooms, telescoped learning, cluster classrooms, subject acceleration, honors/advanced coursework, Advanced Placement (AP) programs, dual enrollment in college, and International Baccalaureate programs. Renzulli (2012) questions why, if we are concerned with developing gifts and talents that result in creative problems solvers, programs for gifted and talented students still focus on the acquisition of content specific knowledge.

Olszewski-Kubilius, Subotnik, & Worrell (2016) explore how the needs of 21st century society intersect with the components of talent development. The authors identify two things as necessary for talent development in the 21st century—exposure to a wide variety of domains, and development of psychosocial skills such as resiliency, positive attitudes, communication, and growth mindsets. Inarguably, for a talent in any domain to develop one must: (a) be exposed to the domain; (b) believe they are capable in the domain; (c) practice in the domain; and (d) not give up if faced with setbacks or challenges.

When identifying potential areas for study in gifted and talented education, Subotnik et al. (2011) pose three important questions: "What kind of programming would best cultivate talent and reveal interest and motivation in early and middle childhood? How can this be infused into pre-school and early elementary-school education?" and, "Can programs be crafted that develop skills and competencies but simultaneously also boost the psychological characteristics needed to sustain commitment and persistence in challenging learning environments?" (p. 38). Olszewski-Kubilius et al. (2016) adds two additional questions: "How will schools ensure that all students have equal access to the new basics, such as programming and technology courses, thereby opening pathways to talent development in those critical domains?" and "How will we identify talent for newly emerging transdisciplinary domains?" (p143). The answer to these questions may be to develop makerspace programs in PreK-12 schools.

To better understand what a makerspace is, the next section defines makerspace, explains the activities occurring in makerspaces, the components of makerspaces, and some potential outcomes as a result of participation in a makerspace.

What is a Makerspace?

In 2005 Dale Dougherty launched *Make: magazine*, and used the term "maker" to describe the individuals who partake in creating items (Dougherty & Conrad, 2016). Broadly defined, a makerspace—sometimes also referred to as a FabLab, hackerspace, or tinkerspace – is a shared space where people, tools, and problems are brought together, and individuals use the tools to solve problems (Dougherty, 2012; Dougherty & Conrad, 2016; Martinez & Stager, 2013). Making is the creation of new knowledge and products (physical or digital), using available tools and materials. Making involves solving problems—real or imagined—alone or in collaboration with others. Makerspace participants are sharing ideas, testing theories, making mistakes, and trying again. Making and makerspaces have ties to centuries of educational theory and practice, including the work of Dewey, Piaget, Vygostky, Montessori, and others. (For one review of the historical and theoretical roots of the maker movement, see Halverson and Sheridan, 2014). Makerspaces are often a place where learners can be exposed to new ideas, new tools, new people, and new talents.

The Variability of Makerspaces

There are several variations in the composition of makerspaces, which makes them difficult to define and make generalizations about. Makerspaces may be open access, where users have free reign to do as they wish with available tools and materials; curriculum based, where users participate in activities aligned to a curriculum; scripted, where users participate in activities designed by a program director or makerspace member, however not necessarily tied to a curriculum; or any combination of these arrangements (Burke, 2013; Chu et al., 2017; Gierdowski & Reis, 2015). In makerspaces participants may work individually, collaborate in small groups, attend workshops, or help to host community events. Although often associated with science, technology, and engineering and math (STEM) learning and outcomes (Chu et al., 2015, 2017; Davis & Mason, 2016; Fields et al., 2018; Holbert, 2016b, 2016a; Kafai et al, 2014; Marshall & Harron, 2018; Papavasopoulus et al, 2017) making also involves, tinkering, crafting, woodworking, fiber arts (Clapp & Jimenez, 2016), as well as combinations of these domains and others. The objective of a maker activity may be to solve a problem, to help another maker, to create a product, or to figure out how a particular tool works.

Participants in makerspaces often create objects to solve problems or to explore concepts. Some examples of physical objects created include marble machines, wind tubes, and circuit boards (Bevan et al., 2015), wind turbines, pipes for home plumbing repair, welded bike chain sculptures (Sheridan et al., 2014), toys for neighborhood children (Holbert, 2016b, 2016a) and artifacts to help conduct science experiments (Chu et al., 2017). Activities run the gamut from designing transportation or food solutions, to working with digital tools and electronics, exploring design, fabrication, music, art, bike repair, woodworking, electronics, silk screening, or computer programing (Sheridan et al., 2014). Participants may be working with 3D printers to design prosthetic devices, creating scaled models to explain conic principles, or designing rocket noses to explore physics concepts (Mersand, 2018). The items created may also be more experientially focused such as community events and partnerships with other organizations like soup kitchens, churches, neighborhood groups, and nonprofit organizations - working to strengthen relationships and meet community needs by solving real world problems (Sheridan et al., 2014).

Makerspaces provide multiple entry points; innovative combinations of traditionally separate disciplines allow for novel approaches to problem solving and design of solutions. In a makerspace multiple activities occur in the same space, and components of different activities often cross-pollinate the work being created. For example, designing a flashing safety vest for bicycle riders combines sewing, computer programming, and electric circuitry; robots are created with a combination of computer programming, physical computing components, cardboard, and LEGOs (Blikstein et al., 2016); a working portable hydroelectric generator is created with plastic cups, plastic spoons, corks, magnets and copper wire (Mersand, 2017). Makerspaces can facilitate opportunities for people to work together in a shared space allowing ideas and skills to comingle, resulting in new ideas and directions that may not happen if working in isolation.

Makerspaces: Tools and Materials

It is not surprising that the availability of tools and materials will vary between spaces given the description of what is created in them. From costly equipment—such as 3D printers, laser cutters, and Computer Numerical Control (CNC) mills—to graveyards of old technology, toys, piles of cardboard, and shelves of scraps that can be repurposed into new things, the tools and materials in a makerspace can be virtually anything.

Items for exploring circuitry include circuit boards, wires, light bulbs, buzzers, generators, doorbells, batteries (Bevan et al., 2015), circuit blocks, paper clips, motors from old toys, speaker cables, voltmeters, soldering irons, oscilloscopes (Sheridan et al., 2014), battery-operated motors, LED lights, and soldering irons (Bowler & Champagne, 2016). Participants explore concepts like light refraction and shadows using littleBits, Arduinos, conductive ink, Snap4Arduino, craft materials, straws, cardboard, and paperclips (Bekker et al., 2015).

Non-digital fabrication tools and materials include sewing machines, thread, needles, pins, bolts of fabric and fabric scraps, foot pedal operated looms (Sheridan et al., 2014), as well as items such as glue guns (Bowler & Champagne, 2016), pre-drilled boards and bolts for building, tools for construction and woodworking, kilns, recycled materials, bits of paper, cellophane, welders, iron pouring tools (Sheridan et al., 2014), pipe cleaners, cardboard tubes, and tape (Bevan et al., 2015).

As noted previously, makers may have access to tools for digital fabrication such as 3D printers and laser cutters (Benjes-Small et al., 2017; Sheridan et al., 2014), as well as digital tools for drawing images, editing photos, remixing video clips, composing music, animating stories (Benjes-Small et al., 2017; Bowler & Champagne, 2016), and creating stop-motion animation (Sheridan et al., 2014). Users may have access to tools and materials to explore computer programming such as wooden blocks for object-oriented programing, (Sheridan et al., 2014), computers (Barron, 2006; Benjes-Small et al., 2017), and robots and robotics materials including microcontrollers (Bowler & Champagne, 2016).

Such variability in materials can change the types and purposes of activities users participate in, as well as the learning outcomes.

Learning Outcomes from Participation in Making Activities

Learning outcomes are often broadly categorized into three domains: cognitive outcomes deal with knowledge and the development of understanding; psychomotor outcomes deal with specific physical skills; and affective or psychosocial outcomes deal with attitudes, beliefs, and feelings (Anderson & Krathwohl, 2001). Due to the array of activities, materials, and objectives in a makerspace, there are a multitude of opportunities for growth in knowledge in and across multiple domains, as well as a multitude of ways to document evidence of learning.

Cognitive and psychomotor learning outcomes. Cognitive and psychomotor outcomes are those most often measured in educational contexts. Existing research has focused very little on cognitive outcomes from participation in makerspaces, however some research has measured cognitive outcomes as expressions of realization, offering explanation(s) for a strategy, tool or outcome, application of knowledge, and striving to understand a particular problem or concept (Bevan et al., 2015). Litts, Kafai, Lui, Walkder and Widman (2017) measured growth in understanding of how circuits work by the ability to sketch a functional circuit, as well as the ability to understand, debug and remix code.

Psychomotor skills in a makerspace may include music editing, bike repair, video creation and editing, silk-screening (Sheridan et al., 2014) as well as mastery of the use of a tool or set of tools (Wilson & Gobeil, 2018). Due to the variations in availability of tools and materials as well as objectives of the projects, participants in a makerspace may learn to solder, knit, draw, balance objects, measure, sculpt, or design. While cognitive and psychomotor outcomes are important, perhaps more important when considering 21st century needs are psychosocial outcomes from participation in such spaces.

Psychosocial learning outcomes. Research on makerspaces has identified diverse psychosocial learning outcomes from participating in maker style learning. Many of the outcomes identified are related, and some are used interchangeably. They are presented here using the terminology from the original authors. Psychosocial outcomes include the development of self-sustained learning practices (Barron, 2006), dispositional shifts in interest in a subject, confidence in a skill (Sheridan et al., 2014), and development of positive self-concept and self-image (Norris, 2014). Psychosocial outcomes also include engagement in terms of motivation and investment in projects and the makerspace (Bevan et al., 2015; Bull et al., 2017), collectively formed interests

(Barton et al., 2016) and engagement in projects based on personal connections (Wilson & Gobeil, 2018). Users in a makerspace may demonstrate initiative and intentionality—including goal setting, seeking and responding to feedback, persisting to achieve goals in the problem space, taking intellectual risks and/or showing intellectual courage, as well as requesting or offering to help solve problems, inspiring new ideas or approaches, or connecting to others' work (Bevan et al., 2015). Users may also demonstrate growth in areas of empowerment in social competencies, confidence, self-regulation, and empathy (Bar-el et al., 2016), as well as the ability to embrace failure as a learning opportunity (Bowler & Champagne, 2016).

The previous two sections explored gifted and talented identification and provided a brief overview of makerspaces. The next section explains how the features and affordances of makerspaces may intersect with gifted and talented identification and development to uncover untapped talents.

The Intersection of Giftedness, Talent Development, and Makerspaces

Returning to questions posed in Subotnik et al. (2011) and Olszewski-Kubilius et al. (2016) this sections explores how making and makerspaces may be the answer to some of the identified queries:

> What kind of programming would best cultivate talent and reveal interest and motivation in early and middle childhood? How can this be infused into pre-school and early elementary-school education? (Subotnik et al., 2011, p. 38)
>
> Can programs be crafted that develop skills and competencies but simultaneously also boost the psychological characteristics needed to sustain commitment and persistence in challenging learning environments? (Subotnik et al., 2011, p. 38)
>
> How will schools ensure that all students have equal access to the new basics, such as programming and technology courses, thereby opening pathways to talent development in those critical domains? (Olszewski-Kubilius et al., 2016, p. 143).
>
> How will we identify talent for newly emerging transdisciplinary domains? (Olszewski-Kubilius et al., 2016, p. 143).

Cultivating Talent and Revealing Interests

Subotnik et al. (2011) identified four categories of gifted and talented individuals based on opportunity and motivation: high opportunity and high motivation, high opportunity and undetermined/low motivation, low opportunity and high motivation, and low opportunity and low/undetermined motivation. Olszewski-Kubilius et al., (2016) explain that "[e]arly exposure to a wide variety of domains is critical to ferret out interest and observe exceptional potential" (p. 141). Carefully designed and operated makerspaces can offer that exposure, thereby revealing interests and potential for development. As explored in the previous sections, makerspaces offer entry points into a variety of domains, including those which are important in the 21st century such as robotics and computer programming. Makerspaces may be one way to address identification of individuals in the low opportunity and undetermined/low motivation category because they offer opportunities for students to work with new tools, new people, and new ideas. The opportunities allow for new interest formation, as well as for practice in areas where interest has been uncovered.

Emerging Transdisciplinary Domains

The cross-pollination of activities and ideas that often happens in a makerspace is what Olszewski-Kubilius et al. (2016) refer to as boundary crossing, or transdisciplinary domains. Due to the variety of activities that may be occurring at the same time in a makerspace, users often experiment with multiple domains to solve the problems before them. Many examples of transdisciplinary activities are found in research on makerspaces. For instance, sewable circuits combine sewing, circuitry, and computer programing as participants create circuits with conductive thread, LEDs and programmable lilyPad Arduino boards (Litts et al., 2017). The Bots for Tots program (Holbert, 2016b) challenges participants to design a toy for a younger child—providing free reign of materials available including repurposed toy parts, laser cut acrylic, sensors, sewn fabrics, and electronic components. As the students work on their designs, they share ideas and offer advice to each other. A third example of a cross-disciplinary project is the design and creation of a solar powered heated and lighted sweatshirt. The participants creating the project work with mentors who teach them to sew, how to understand electricity usage, and simultaneously receive fashion advice from other makers (Barton et al., 2016). These types of cross overs, and the advice and skill sharing between participants and mentors may help to prepare students for emerging and transdisciplinary domains important to meet the needs of the 21st century.

Infusion and Equal Access

As previously noted, makerspaces offer users opportunities to explore domains such as computer programing, robotics, engineering, and other technology related domains (among others); they offer opportunities to engage in problem solving, creative thinking and inquiry. Makerspaces are currently being created in schools and school libraries in the United States and throughout the world. A preliminary analysis of the prevalence of makerspaces in PreK-12 school libraries in New York State during the 2016-2017 school year indicates that 30% of schools in the sample (n = 541) already have a makerspace in the school building, with 83.4% of those makerspaces (136/163) located in school libraries (Mersand, 2019). Because school libraries serve all students, in all classrooms, at all grade levels, the creation of an open-to-all makerspace in the school library may be one way to cultivate interest in new domains for talent development and ensure equal access to the resources and programs offered. In fact, the creation of makerspaces in school libraries may also meet a need identified to transform competency into expertise—"[b]eing an 'organized knower'—knowing what you need to know, what is important to know, how to get it, store it, and retrieve it efficiently" (Olszewski-Kubilius et al., 2016, p. 146)—these skills are a substantial part of the standards school librarians are tasked to teach (American Association of School Librarians, 2018a, 2018b).

Development of Skills in Conjunction with Psychological Characteristics

Psychosocial skills identified as important to talent development include motivation, productive mindsets, psychological strength, social skills, resiliency, positive attitudes, communication and growth mindsets (Subotnik et al., 2011). As noted in the previous section, makerspaces can offer opportunities to develop skills such as problem solving, as well as domain specific skills. In conjunction with such skills, makerspaces encourage students to take risks, and embrace failure; students build a sense of community, and collaborate to solve problems through design (Sheridan et al., 2014). The collective nature of a makerspace allows for the development of collaboration skills, and keeps participants engaged when they hit roadblocks, helping them to persevere through problems and setbacks by providing encouragement and advice (Barton et al., 2016; Holbert, 2016b).

Research on making and makerspaces has found the potential for makerspace participation to positively affect the psychosocial skills identified as important for talent development:

- Motivation
  - motivation (Bevan et al., 2015; Bull et al., 2017; Chu et al., 2015; Hughes, Fridman, & Robb, 2018)
  - self-sustained learning practices (Barron, 2006)
  - self-directed learning (Flores, 2017; Wilson & Gobeil, 2018)
  - goal setting (Bevan et al., 2015)
- Opportunities taken
  - initiative (Bevan et al., 2015)
  - empathy (Bar-el et al., 2016)
  - interest (Chu et al., 2015; Hughes et al., 2018; Sheridan et al., 2014)
- Positive attitude
  - self-efficacy (Chu et al., 2015; Davis & Mason, 2016; Sheridan et al., 2014)
  - self-image (Norris, 2014)
  - attitudes toward learning (Bevan et al., 2015)
  - confidence (Bar-el et al., 2016; Flores, 2017; Hughes, et al., 2018; Sheridan et al., 2014)
- Resiliency/growth mindset
  - persistence (Bevan et al., 2015; Hughes, et al., 2018)
  - ability to embrace failure as a learning opportunity (Bowler & Champagne, 2016).
  - risk taking (Bevan et al., 2015; Flores, 2017)
- Communication/social skills
  - empowerment in social competencies (Bar-el et al., 2016)
  - leadership (Sheridan et al., 2013; Hughes, et al., 2018)
  - collectively formed interests (Barton et al., 2016)
  - collaborative skills (Hughes, et al., 2018)

Olszewski-Kubilius et al. (2016) note that online communities of practice such as out-of-school learning can be important in the development of talent domains because of the social support and the interest driven, self-initiated learning that occurs. Olszewski-Kubilius et al. indicate that educators should "leverage the enthusiasm and creativity of work being done through these communities of practice for increased commitment of achievement in school" (p.144).

Lave (1991) explains that communities of practice rely on apprenticeship models, where mastery in a trade is achieved through interaction with others. Lave (1991) describes peripheral participation as the means by which knowledge is acquired, not necessarily through direct teaching, but by observing, taking note, and becoming involved. Lave (1991) explains that situated learning and communities of practice allow for the formation of identity, not just the acquisition of knowledge and skills.

Makerspaces are often described as communities of practice, and participants may shift roles depending on the project and skills required. Makerspaces have been compared to gyms, with members, trainers, and spotters who guide one another as they work to build a repertoire of skills (Sheridan et al., 2014). Each member may at any point be a learner, a trainer, a teacher, or a workshop facilitator, depending on their expertise in any given area, but not necessarily their chronological age (Sheridan et al., 2013). Participation in such an environment may be key in the development of the psychosocial skills necessary for talent development, and to solve emerging societal problems.

Conclusions and Recommendations

As society's needs increase in complexity, how do we foster a citizenship able to imagine the solutions? As Cantor (2021) asserts "[t]alents and skills are ubiquitous. Education should be designed to reveal the talents and skills in each child" (p. 16). School based learning is frequently language based and taught out of context; students read from textbooks and listen to teachers lecture, rendering subjects like science and math irrelevant. Students are taught facts about a topic, but they aren't typically taught how the concepts relate to actual practice.

> Imagine a textbook that contained all of the facts and rules about basketball read by students who never played or watched the game. How well do you think they would understand this textbook? How motivated to understand it do you think they would be? (Gee, 2007, p. 22)

Martinez and Stager (2013) make a similar argument in *Invent to learn: Making, tinkering, and engineering in the classroom*. Students are not learning through hands on projects as they will need to learn in the field. Programs and services focused on students' academic abilities diminish the opportunity to identify and develop talents in other domains. Makerspaces may provide a new opportunity structure, a way for learning to become contextualized. Makerspaces, if designed with intention, may provide a context in which learning is necessary and tied to real-world problems.

Makerspaces can function as an enrichment opportunity or be incorporated within the traditional curriculum. Research supports that makerspaces benefit all students by developing what Olszewski-Kubilius et al. (2016) identify as the talents necessary to contribute in the 21st century. A school based makerspace can and should operate in a manner that allows all students to use them in a variety of ways: of their own free will, in connection to the curriculum, and in conjunction with clubs and activities. Makerspaces provide opportunities for students to interact with tools, problems, experts, and peers on any number of skills in any number of domains. Students may learn how to use a screwdriver or soldering iron from a peer, they may learn to knit a row on a scarf from a community member, and they may come to realize a new interest through exposure to new tools, ideas, and ways of looking at the world. Makerspaces have the potential to afford everyone the opportunity to develop both domain-general and domain-specific talents. They may be a means by which learners can be exposed to new ideas, domains, and communities.

At the same time, they may be a way to help develop students' civic orientation. Living labs, community-based co-creation spaces similar in composition and ethos to makerspaces, have been identified as a potential intermediary of public innovation (Gascó, 2017). Living labs bring together citizens, governments, private industry, and community organizations to solve societal problems—and skills. Makerspaces in schools may be designed in such a way that students are working with policy makers and other stakeholders to solve problems local to their schools and communities. They may be a way to develop the "wisdom to help to ensure that their skills are utilized to achieve a common good that balances their own (intrapersonal) interests with other people's (interpersonal) and institutional (extrapersonal) interests over the long term, not just the short term" (Sternberg, 2015, p. 77).

A Research Agenda

Makerspaces, if intentionally designed and implemented, can be an environment where students engage in activities alone or in groups, with peers or with adults, and offer opportunities to interact with materials and tools that are not always available in schools or homes. They can allow for transdisciplinary learning opportunities that break the typically siloed mold of education. They may be a way to develop communities of practice around shared goals and interests in schools and communities to develop solutions to 21st century problems.

Although research on making and makerspaces is a growing area, studies are needed to investigate:

- What opportunities, risks, and challenges are associated with the formation of school-based makerspaces to address 21st century societal problems?
- What barriers and enablers exist regarding the formation of communities of practice in school-based makerspaces?
- How and to what extent do school-based makerspaces foster identified 21st talent needs?

- How and in what ways are psychosocial constructs operationalized, observed, and measured in school-based makerspaces?

The study of makerspaces may illuminate novel opportunities and strategies for identifying and nurturing the gifts and talents of students, as they provide opportunities for students to: (a) be exposed to new domains; (b) believe they are capable in the domains; (c) practice in the domains; and (d) not give up if faced with setbacks or challenges.

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