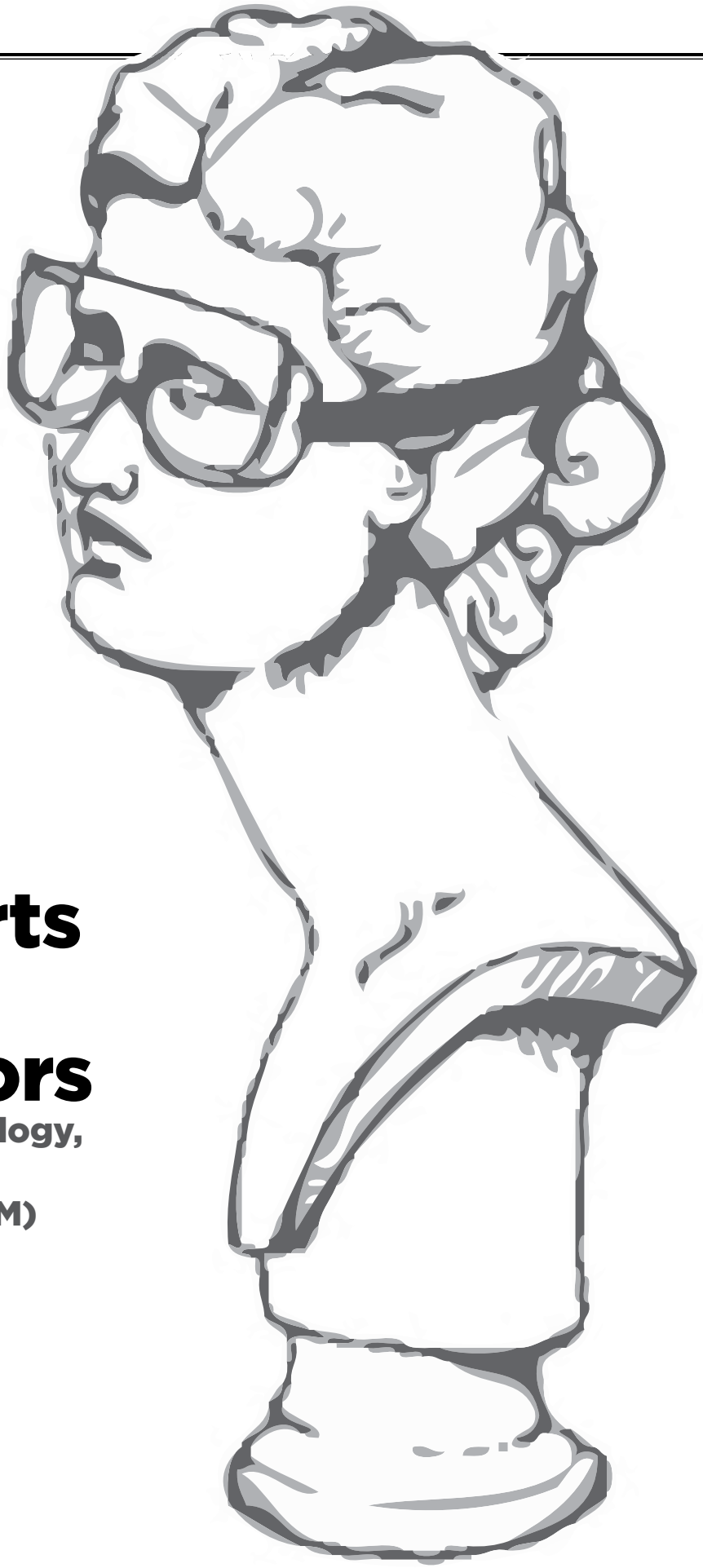

ArtSmarts Among Innovators

in Science, Technology, Engineering, and Mathematics (STEM)

MICHIGAN STATE
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Executive Summary

During times of economic crisis, those in charge of school and public resource budgets often eliminate arts, music, dance and craft opportunities. The assumption is, in part, that arts and crafts are frills that are dispensable. Research suggests, however, that disposing of arts and crafts may have serious negative consequences for Michigan's ability to produce and attract innovative scientists and engineers who invent patentable products and found valuable new companies. Our study of Michigan State University Honors College science and technology graduates (1990-1995) has yielded four striking results:

1. Honors College graduates majoring in science, technology, engineering, and math (STEM) subjects are far more likely to have extensive arts and crafts skills than the average American.
2. Arts and crafts experiences are significantly correlated among these graduates with producing patentable inventions and founding new companies.
3. The vast majority of these graduates believe that their innovative ability is stimulated by their arts and crafts knowledge. When asked, many of these innovators and entrepreneurs recommend increasing the amount of exposure science and technology students get to arts and crafts.
4. Lifelong participation and exposure in the arts and crafts yields the most significant impacts for innovators and entrepreneurs.

These findings suggest that art, music, dance, and crafts are useful, valuable, and essential components for the economic recovery of Michigan and the nation. We therefore recommend that public policy makers:

1. Recognize the utility of arts and crafts in supporting innovation in science, technology, engineering, and mathematics.
2. Recognize that funding of arts and crafts is a critical component of supporting Michigan's economic transformation.
3. Support research that investigates the most efficient and effective ways to provide arts and crafts exposure throughout the lifespan to foster economic development through innovation.

Michigan's economic recovery and development may depend on educational and community ArtSmarts.

ArtSmarts Among Innovators

Arts and Economic Development

Current thinking argues that cultural assets, such as thriving arts sectors, play an important role in generating and sustaining a globally engaged economy. A community's creative and cultural assets have three primary effects. First, a thriving arts sector functions as a jobs generator with direct economic benefits. Cultural assets, including art museums, orchestras, theatres, galleries, and ongoing arts education opportunities, serve as a source of jobs for personnel in the arts. According to the 1997 U.S. Economic Census, there are approximately 67,000 people employed in the creative enterprises of Michigan (Fernandez, Garg, & LaMore, 2005). Second, a thriving arts sector functions as a magnet for other innovative businesses. Cultural assets provide an enhanced quality of life that attracts and retains highly skilled, highly paid knowledge workers and innovators (Florida, 2002). Finally, an arts-enriched environment may also stimulate the creative capacity of current and future generations of workers (Pink, 2005). This study aims to explore how sustained training or involvement in the arts can lead to professional success in areas of science and innovation.

Arts training and involvement can be key to attracting STEM innovators and building an innovative economy.

Background Research

In 2002, social scientist Richard Florida changed the economic development paradigm by introducing the concept of the creative class and proposing the idea that the creative class plays a crucial role in the knowledge economy. The creative class is a socioeconomic class made up of scientists and engineers, university professors, poets, and architects. It also includes "people in design, education, arts, music and entertainment, whose economic function is to create new ideas, new technology and/or creative content" (Florida, 2002, p. 8). Because of their knowledge-based jobs, Florida asserted that members of the creative class tend to contribute directly to the growth of a thriving economy. Equally important, members of the creative class tend to prefer those jobs in geographical locations with high levels of culture and diversity. Florida thus argues that regions which support the arts will attract and retain the creative class and, consequently, enjoy higher levels of economic prosperity. This study addresses the role of arts exposure in the life of innovators. We explore whether arts exposure and arts practice play any role in nurturing the innovative thinking of science/technology entrepreneurs. Additionally, we aim to understand how and why the creative class—science and technology entrepreneurs in particular—may be attracted to communities rich in arts opportunities.

Research suggests that exposure to the arts can develop creative potential in the young (Western Michigan University Research Foundation, 2005). Creative potential, in turn, enhances problem-solving and critical thinking skills essential to success in an information- and innovation-based economy. For example, students with four years of arts or music classes in high school and college score higher on the Standardized Aptitude Test (SAT). These students score an average of about 130 more points on verbal and 70 points on math and tend to earn higher grades than students who are not engaged in any fine arts; see for example National Association for Music Education (MENC), 2008. Overall, the impact of arts education is greater than the impact of science education or computer training on raising overall SAT scores.

The scholarly study of eminent individuals suggests that arts training and involvement achieves such ends by influencing certain styles of thinking consistent with creativity and innovation. More than a century ago, Nobel

Laureate J. H. van 't Hoff investigated several hundred historical figures in science and concluded that the most innovative among them almost invariably had one or more creative avocations (Root-Bernstein, 2001; van 't Hoff, 1878). These avocations often included crafts, arts, creative writing, and music. More recently, historian of science Paul Cranefield found that among the men who founded the discipline of biophysics, there was a direct correlation between the number and range of avocations each individual pursued, the number of major discoveries they made, and their subsequent status as a scientist (Cranefield, 1966). Billington (1985, 1997) and Hindle (1981) have shown that many 19th and 20th century engineering innovators were trained as fine artists and architects. Ferguson (1992) has made the case that invention is virtually synonymous with visual thinking, drawing and making models. A robust body of education research demonstrates that success in engineering is dependent on well-developed visualization skills (Deno, 1995; Lord, 1985; Sorby & Baartmans, 1996). Root-Bernstein, et al. (1995) found that visualization ability was correlated with arts and crafts experience. Several other studies found that students who were given instruction in drawing scored higher on visualization tests as well as classroom performance in engineering and science classes (Alias, Black, & Grey, 2002; Deno, 1995; Lord, 1985; Sorby, 2009; Sorby & Baartmans, 1996).

Building on this research, Root-Bernstein and colleagues (Root-Bernstein, Allan, Beach et al., 2008; Root-Bernstein, Bernstein, & Garnier, 1995; see also Root-Bernstein & Root-Bernstein, 2004) have shown that eminent scientists are significantly more likely to be engaged in fine arts and crafts as adults than are their less successful colleagues. In interviews, scientists describe useful interactions between their artistic activity and scientific work, including improved mental skills, better hand-eye coordination and tool use, more creative imagination, better communications skills, greater aesthetic appreciation of their work, and a wider range of social and professional contacts. These same arts avocations and attendant skills also correlate with high degrees of scientific innovation, whether measured by paper citations or awards such as the Nobel Prize. Root-Bernstein et al. (1993, 1995, 2004, 2008) found that scientific success (as measured by a variety of measures including various forms of impact, Nobel Prizes, or election to the U. S. National Academy of Science or the British Royal Society) is correlated with the practice of fine arts and crafts into adulthood. In one large study comparing 510 Nobel Prize winners with 4406 members of the Sigma Xi Scientific Research Society,[1] Nobel laureates were at least 15 (and as much as 35) times more likely to have an arts or crafts avocation as an adult (Root-Bernstein et al., 2008).

As past studies indicate, arts and crafts teach styles of thinking associated with successful innovation in the sciences and technologies.

Thus far, however, there have been no formal studies of the role that arts may play in stimulating, nurturing or producing creative capacity among inventors and entrepreneurs. Our study examines the formal and informal training of innovators, entrepreneurs and engineers in Michigan to determine what type of arts exposure, at what stage, influences their creative capacities.

1 Sigma Xi is an international research society whose programs and activities promote the health of the scientific enterprise and honor scientific achievement. Membership is by invitation only. There are nearly 60,000 members in more than 100 countries around the world. The Society endeavors to encourage support of original work across the spectrum of science and technology and to promote an appreciation within society at large for the role research has played in human progress.

Michigan's Knowledge Economy: Policy Relevance of the Research

The state of Michigan appears to be caught in a self-perpetuating cycle of unemployment and brain drain.[2] Michigan has experienced a decade-long stretch of job loss. Currently, the state has the highest unemployment rate in the nation, at 13.1% (as of June, 2010; U.S. Bureau of Labor Statistics, 2010), compared to 5.2% unemployment in 2001 (U.S. Bureau of Labor Statistics, 2010). The industries which have historically driven the state economy (e.g., automotive, agriculture, and tourism) are paying less and fewer jobs are available. In 2009, the average factory wage was about $35,000 a year, compared with the 2007 average income of $38,564. During this same period, sectors which do not require higher education lost more than 288,000 jobs.

High-education industries in Michigan also lost 18,655 jobs from 2001 to 2007 (Glazer & Grimes, 2010).[3] This produces an especially challenging cycle of unemployment leading to the loss of our skilled workforce. From 2001-2007, Michigan's per capita income growth was half that of states with industries requiring higher levels of education and with higher concentrations of workers with four-year degrees. In some cases, income in states with more knowledge-driven economies grew at a rate double the growth in Michigan (Glazer & Grimes, 2010). Economic migration trends show that Michigan's net retention of young, highly educated people continues to decline. Nearly 35,000 young knowledge workers left the state during 2007, while 18,000 entered from another state or abroad—the lowest national rate of in-migration (Michigan Department of Labor and Economic Growth, 2009, p. 10).

In 2000, Michigan ranked 16th in the nation for per capita income; by 2007 the state had dropped to 33rd in the nation. The mean annual income in Michigan for all occupations was about $43,000 or about $20 an hour (median hourly rate is about $16) in 2009. For architecture and engineering occupations, the mean income rises to about $72,000; this figure is comparable to national averages. Chemists and physicists working in Michigan make over $90,000 a year. Chemists are paid slightly higher, and physicists slightly less than their respective national averages ($88,500 for chemists and $111,000 for physicists).

These statistics paint a sad picture of the change occurring in Michigan. Specifically, loss of jobs and the loss of the creative class impact the health of the economy as a whole. The tantalizing prospect that a revitalized dedication to arts and arts training in Michigan may help reverse this trend calls out for attention. At present, public policy decisions often decrease or eliminate funding for the arts and cultural assets of communities, assuming that they are expendable "extras." This may be a serious policy error based on a set of false assumptions. Without clear knowledge of the arts' role in building general creative capacity, the long-term costs of this approach cannot be adequately assessed. Funding reductions may inadvertently stifle the technology-inventing capacity of current and future Michigan generations. This reduced capacity for invention, along with a weakening of the cultural environment necessary to attract innovative businesses and personnel from outside the state, may in turn inhibit local development of an entrepreneurial, high-tech economy capable of competing on a global scale.

This study examines how arts and crafts experience helps to grow a "creative class" of successful entrepreneurs.

Emerging critical research suggests that the local and regional development of innovative science and technology

2 Brain drain refers to the emigration of individuals with technical skills or knowledge due to lack of opportunity.

3 The knowledge-based part of the economy is defined as those industries where the proportion of employees with a bachelor's degree or more is at least 30 % (110 % of the national average of adults with a bachelor's degree or more).

economies may depend in no small part on the quality of community arts (Florida, 2002). Within this field of inquiry little attention has been paid, however, to the role arts education and training may play in stimulating the professional inventiveness of technology workers and entrepreneurs. A recent study of large numbers of scientists suggests that the most eminent and innovative among them are significantly more likely to engage in arts and crafts avocations than the average practitioner (Root-Bernstein et al., 2008). Phenomenological study of individual scientists additionally suggests that they derive from arts avocations imaginative and creative skills of direct professional benefit.

To test this art-science connection, the current research project investigates the ArtSmarts of Michigan State University Honors College graduates from 1990 to 1995 who majored in science, technology, engineering, or mathematics. The advantage of studying this group is that all survey participants have had time to establish careers, were trained within a single educational setting, and were selected according to a common set of college admissions criteria. The possible impact of variables other than arts and crafts participation is thus minimized. Our analysis involves a study of formal and informal arts and crafts education and ongoing arts and crafts exposure in relation to papers published, patents granted or companies founded. We pose the following research questions:

- Does arts and crafts involvement have any relationship with economic development?
- Do innovators and entrepreneurs use the skills they develop through arts and crafts involvement for problem solving?
- Do STEM graduates report higher than average arts and crafts training or hobbies?

We hypothesize that arts avocations correlate with increased levels of scientific and technological innovation. Thus, increased involvement in arts and craft increases individual innovative capital. We further hypothesize that sustained training or involvement in the arts can predict professional success in science and technology.

The study investigates whether STEM graduates of Michigan State University's Honors College who also participate in arts and crafts have more innovative and entrepreneurial careers than STEM classmates who do not.

Methodology

A web-based survey was sent out via e-mail to MSU Honors College graduates who earned a degree between 1990 and 1995. The Honors College at Michigan State University is among the nation's most distinctive and extensive honors programs. The College strives to ensure an enriched academic and social experience for its members and to create an environment that fosters active, innovative learning.

Our sample included 270 individuals who had a valid e-mail address.[4] Eighty-two surveys were returned, giving us about a 30% response rate. Of the surveys received, the respondents were sorted according to STEM undergraduate majors and non-STEM majors. STEM majors included science, technology, engineering, and mathematics. Of the 82 responses, 44 were identified as STEM majors.

4 Of the 298 invitations, 28 e-mail IDs were invalid.

This group was analyzed based on a series of self-reported arts involvement measures. Arts experiences were assessed for three life phases: childhood, young adult, and mature adult. For the purposes of this analysis, childhood involvement refers to art lessons and hobbies until the age of 14; young adult, from 15 to 25 years old; and mature adult, over 25 years of age. Involvement was assessed by counting reported activities in an art or craft for each life phase. Lifetime involvement is defined as training or involvement in one or more than one life phase. We defined sustained involvement as ongoing training or involvement over all phases—throughout childhood, young adulthood, and mature adulthood.

Our survey instrument included a list of 23 arts and crafts, ranging from photography to metal work to fiction writing (see Appendix A for a list of items). Participants indicated which arts or hobbies they were involved in. Participants also reported the type of training: in school, private lessons, mentoring, or self taught. The aggregate of reported arts provides a measure of the level and type of arts experienced as a child, as a young adult, as a mature adult, and at any time in life.

What is the relationship between arts involvement and economic development?

To explore whether arts and crafts involvement correlates with innovation and entrepreneurship, we explored the concept of creative capital. Creative capital is used to describe the economic value of creative production. In this analysis, we focus on patents and companies in order to assess economic value. Specifically, we compared levels of arts and crafts involvement among MSU STEM Honors College graduates who have either founded companies or produced patents with the levels of involvement of graduates that have not founded companies or produced patents.

As an additional measure, we investigated whether any arts or crafts were associated with total creative capital as measured by an aggregate of all peer-reviewed publications, books, patents, or companies. Our reasoning is that those with the highest number of publications, books, patents, or companies produce the most creative capital. This latter investigation compared the most creative 10% of the respondents to the other 90% of the respondents. This type of analysis is based on the Pareto principle, a well-known economic observation that a majority of participants in any economic endeavor produces a small fraction of the total output, while a small minority of participants produces the vast majority of the output (Pareto distribution, Pareto principle, 2010).

In general, STEM Honors College graduates who have founded companies or produced patents have higher than average exposures to some arts and many crafts than do STEM Honors College graduates who have not founded companies or patented inventions. Looking first at the childhood life phase, the data show a positive relationship between involvement in arts and crafts and producing patents or founding companies (see Table 1). The same is true for young adults (see Table 2) and mature adults (see Table 3), albeit we find a different set of crafts and arts activities for each stage associated with patents and companies. That is to say, the pattern of which arts correlate with patents and companies varies across the different life stages.

Table 1: Statistically Significant Childhood Arts and Crafts and Creative Capital

	Patents	*Companies*	*Overall*
Pottery/Ceramics	✓		
Photography	✓		
Woodwork	✓		
Metal Work	✓	✓	✓
Mechanics	✓		
Electronics	✓	✓	
Architecture		✓	
Computer			
Programming	✓		

Table 1 illustrates the relationship between participation in arts and crafts and the production of creative capital. The childhood arts and crafts participation analysis suggests that people who were involved in pottery/ceramics, photography, woodwork, metal work, mechanics, electronics, and/or computer programming as children were more likely to have a patent as an adult. Involvement in metal work, mechanics, electronics, or architecture in childhood has a positive relationship with companies founded. Metal work involvement in childhood was related to all creative capital (i.e., patents, companies, and publications).

Table 2: Statistically Significant Young Adult Arts and Crafts and Creative Capital

	Patents	*Companies*	*Overall*
Pottery/Ceramics			✓
Mechanics	✓		
Electronics	✓		
Architecture	✓		
Computer Programming	✓		

We also found a relationship between young adult involvement in mechanics, electronics, architecture, and computer programming, and patents in adulthood. Pottery and ceramics were related to all of our economic measures (patents, companies, and publications).

Table 3: Statistically Significant Mature Adult Arts and Crafts and Creative Capital

	Patents	*Companies*	*Overall*
Photography	✓		
Print Making	✓	✓	
Composing Music	✓	✓	
Magic	✓		
Metal Work	✓		
Mechanics	✓		
Electronics	✓		
Architecture	✓		

Table 3 illustrates the relationship between participation in arts and crafts as a mature adult and the production of companies, patents, and publications. Those involved in print making, composing music, magic, metal work, mechanics, electronics, or architecture as a mature adult also tended to have more patents. Print making or composing music as a mature adult was positively related to all creative capital. Involvement in photography as a young adult was related to companies founded (see Table 3).

Table 4: Statistically Significant Sustained Arts and Crafts and Creative Capital

	Patents	*Companies*	*Overall*
Photography	✓		
Composing Music			
Dancing		✓	
Magic	✓		
Woodwork	✓		
Metal Work			
Mechanics	✓		
Electronics	✓		
Computer Programming	✓		

Finally, we looked at which activities, if sustained over a long period of time, correlate with patents, companies, and overall creativity. Sustained activities are those that are practiced at every stage of life from childhood through mature adulthood. Here, the data suggest that ongoing involvement in photography, magic, woodwork, mechanics, electronics, or computer programming is related to producing inventions that yield patents. Sustained involvement in dance is related to companies founded (see Table 4).

In sum, individuals who produce creative capital as adults are much more likely than those who do not produce creative capital to be involved in a sustained manner with one or more crafts or arts such as music composition, dance or photography. These data suggest that long term experience with the creative process in arts and crafts may enhance creative potential in science and technology.

Among MSU STEM grads early and ongoing participation in many crafts and some arts correlates with making patentable inventions and founding companies in adulthood.

These findings suggest that participation in various arts and crafts correlates with the production of patentable inventions and the founding of new companies and can differentiate the entrepreneurs from less innovative individuals even among a group of highly successful individuals, such as Honors College STEM professionals. While causality cannot be determined by these preliminary and explorative findings, the data do indicate that arts and crafts education and ongoing participation are correlated with economic development, and that eliminating arts and crafts programs may have serious long-term economic consequences.

Do innovators and entrepreneurs use the skills they develop through arts involvement for problem solving?

In order to move beyond correlation toward causality in the relationship of arts and crafts to innovation, we asked STEM graduates to comment on the roles that arts and crafts skills play in their professional work. We asked the following questions and received the following replies.

Does your avocation or hobby – or the skills, knowledge, esthetic, social contacts, creative practices, or just plain perseverance that you have gained from it – play any role in your current vocation? If so, please explain how.

36 respondents: Yes/Certainly: 21 (58.3%); Maybe: 5 (13.9%); No: 10 (27.8%)

I believe participating in other activities (arts-related) helps engage other parts of your mind that may not be used every day at work and allows greater problem-solving capacity.

[My crafting] helps me relax and think of alternatives and ways of defining problems.

Certainly. These hobbies have assisted with problem solving when resources are scarce or different. In cooking for example we often encounter the need to improvise when ingredients are scarce or unavailable.

Quilting is a great way to use creativity and analytical thinking to solve problems and create something that is aesthetically appealing. It helps me lower my stress level, and likely improves my creativity in my current vocation.

My crafting gives me some quiet reflection time—allows my brain to subconsciously and consciously think through problems.

Absolutely. I've always had an eye, even when I was in politics and working in the nonprofit world, I gravitated toward designing the newsletter or conference materials. I think through problems as creative solutions.

I use some of my skills from drawing for creating stimuli for experiments. Experience with visual composition helps to create good diagrams and presentations.

General creativity and ability to consider multiple possibilities when troubleshooting. Able to get out of/avoid the "this is the way we've always done it" ruts.

Perseverance, patience, and play are all components built by my avocation/ hobbies.

Would you recommend arts and crafts education as a useful or even essential background for a scientific or engineering innovator? Why or why not?

36 respondents: Yes/Absolutely: 29 (80.6%); Maybe: 5 (13.9%); No: 2 (5.6%)

Yes, expands horizons and helps to think outside the box.

Yes, allows you to explore materials in a different way, figure out how to put things together, try to do things differently.

Yes. Not necessarily a "curriculum," but the chance to dabble and see how things work together. After these many years in the classroom, I see those that have music and arts background seem to do very well in physics and oftentimes head to engineering careers.

I find that most scientifically minded people I know well have an interest in art or craft as well. I do think that it is an opportunity to perceive the world in a different way and engage a different portion of the brain.

Diversity of experience helps you look at a problem in a different way than it has been looked at before.

Absolutely. Some of the greatest inventions and innovations have come from individuals who were not experts in the field. Many discoveries stem from the application of a tool in one field to another. The wider one's breadth, the greater the likelihood of discovering these connections.

I think arts and crafts education is essential for all vocations. These things teach both hard skills and experimentation and essentially school you in that magic intersection of the two, where you might know all the technical aspects of taking a good photograph but still have to intersect that with the art of an eye or composition or unusual processing. It's what makes art art. Technical excellence matched with creativity and play.

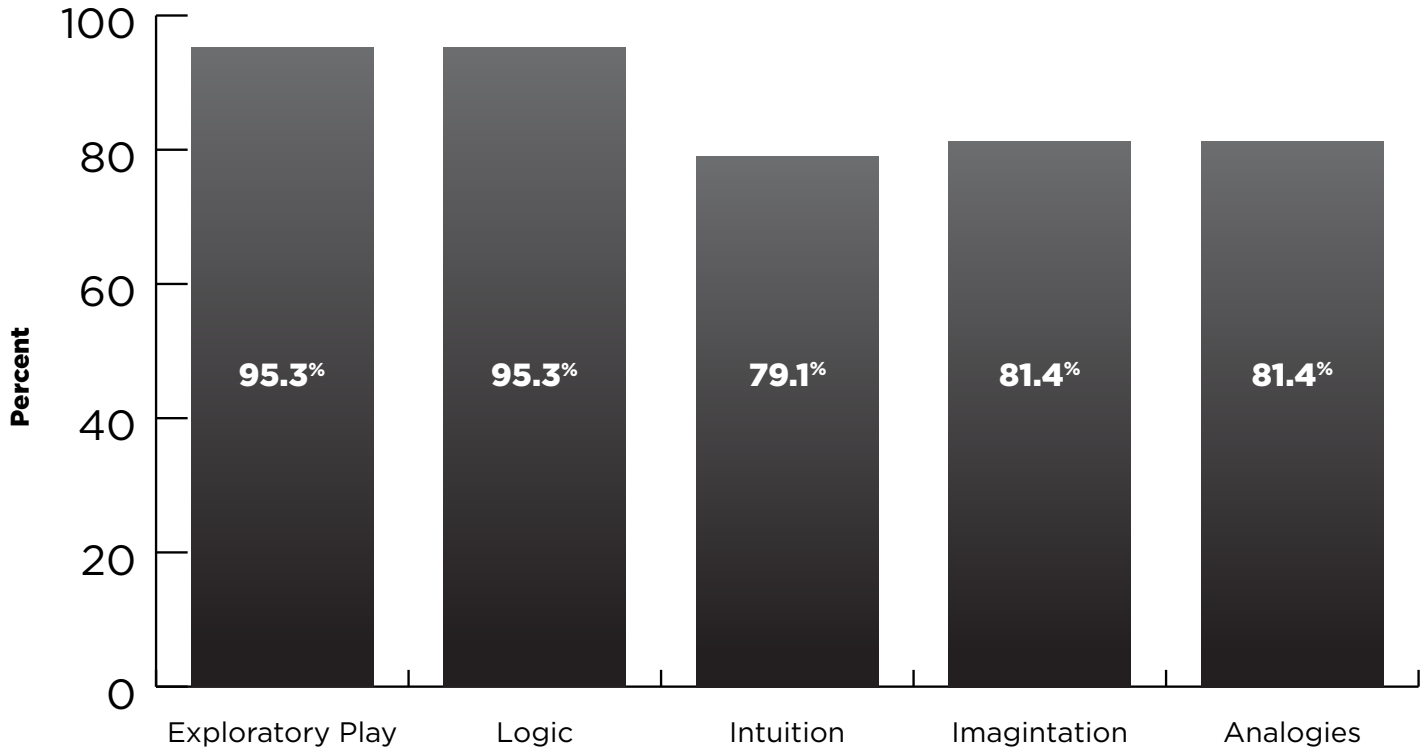
Yes, definitely. Arts and crafts encourage experimentation—there's no one right way to do art. It encourages one to break out of a "follow the steps to get some result" mold. I feel like I am adept at getting my bearings in unfamiliar situations and determining a direction to follow. This is very helpful when troubleshooting, where the unexpected happens all the time.

The responses to our questions to the MSU STEM graduates overwhelmingly place a very high value on knowledge and skills acquired through participation in arts and crafts.

80% of STEM professionals report that arts and crafts deliver skills necessary for innovative work in science, technology, engineering, and mathematics.

In addition to interviewing the STEM professionals about the relationship of arts and crafts skills to their professional work, we also asked them to report what types of cognitive tools they use for problem solving. While some tools they use are scientific in nature, such as "logic," other tools are more often associated with artistic thinking, such as the use of "analogies," "playing," "intuition," and "imagination." The results are shown in Figure 1.

Figure 1: Cognitive Styles of Professional Problem Solving

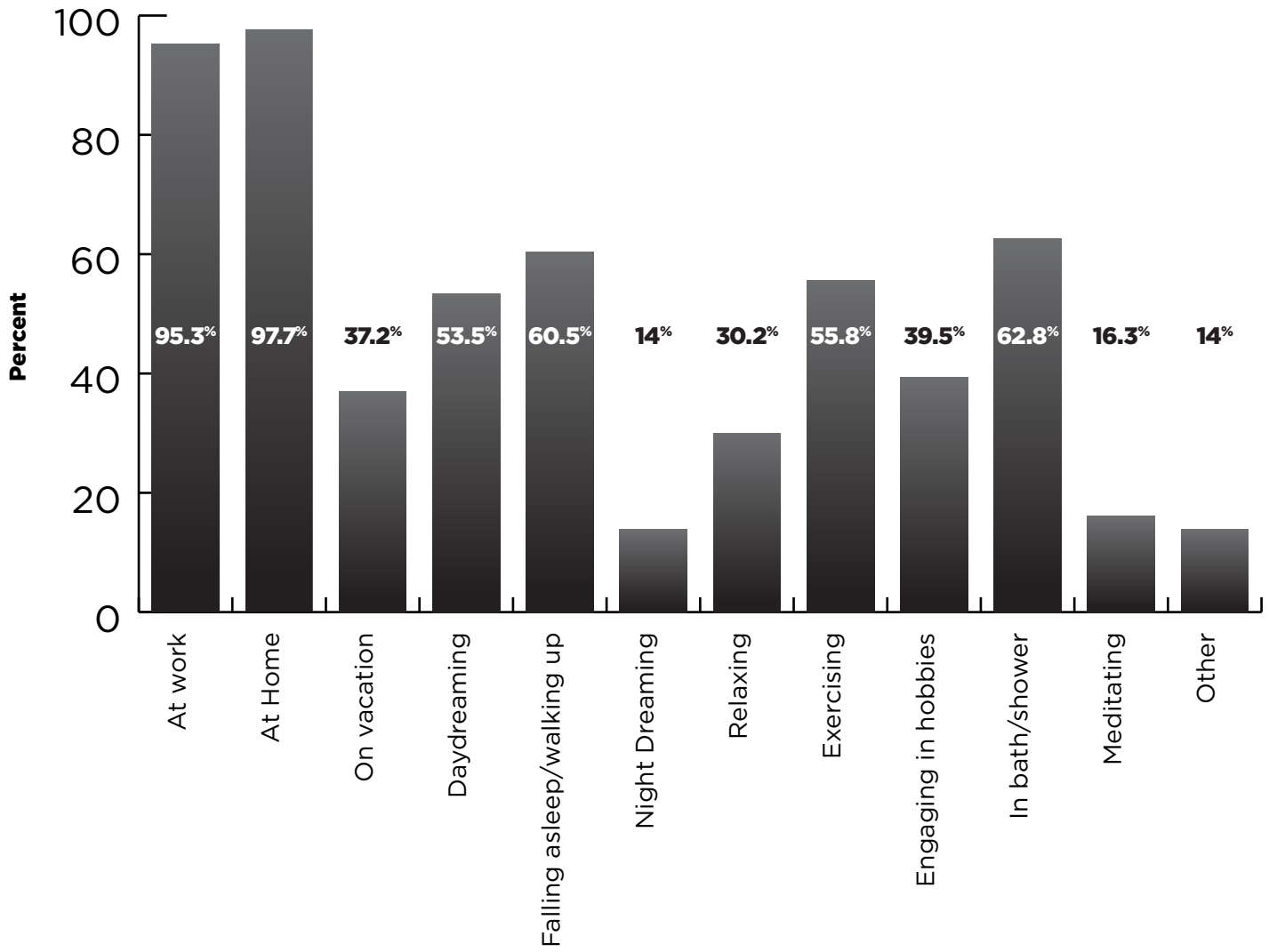


As one would expect of science and engineering professionals, the vast majority (95.3%) reported using logic while doing their work. Verifying the importance of arts and crafts training to innovative science and engineering, an overwhelming majority also reported using "artistic" styles of thinking: 95.5% reported using exploratory play as a method of problem solving, 80% reported using either intuition, imagination or both, and about 80% reported using analogies. In other words, these successful STEM professionals use "artistic" types of thinking at work just as often as they use stereotypical "scientific" modes of thinking. As the quotations reproduced above demonstrate, many of these individuals were very specific in reporting that arts and crafts were important for developing their intuitive and imaginative styles of innovative thinking.

STEM professionals report using artistic forms of thinking such as playing, analogizing, intuition, and imagination as often as scientific logic.

We also asked STEM honors graduates about the environments and activities that foster or invoke creative thinking. More than 95% of our sample reported creative problem-solving at work, but nearly 98% also reported such problem-solving at home. Common activities conducive to creative thinking at home included falling asleep, waking, exercising, and taking a bath or shower. Notably, many respondents reported having some of their best ideas while relaxing or doing their hobbies, again emphasizing the importance of their arts and crafts as means of stimulating their creativity and productivity.

Figure 2: Problem-Solving Environments and Activities



Creative problem solving occurs outside the workplace as often as within.

Do inventors and entrepreneurs report higher than average arts experience?

Finally, in order to examine how much arts and crafts exposure STEM professionals get compared with the average individual, we compared the STEM Honors College graduates with the general public. Statistics involving the average arts experiences of American adults were made available through the National Endowment for the Arts (NEA). The NEA collected data from a cross-section sample of 12,736 households between 1982 and 1993 (Robinson, 1993). The NEA statistics worked as our baseline sample in order to compare the levels of arts between STEM graduates and the general population.

For this analysis, we compared the percentage of the general public who reported taking any music lessons with the percentage of STEM graduates who indicated taking lessons or having classes in music, composing,

or singing. We did the same comparison for visual arts; this includes people who report any drawing, painting, sculpting, print making, or film/video making through lessons or classes. Dance includes any lessons or classes in dance at any life phase. Creative writing includes any writing, poetry, or nonfiction writing courses at any life phase. In each case, a higher percentage of STEM graduates received lessons than either of the NEA populations. Most notably, an overwhelming majority (93%) of STEM graduates had music training at some point in their life.

Table 5: STEM Honors College Graduates Compared to NEA Sample

	Percent of STEM Honors College Graduate	*Percent of NEA (General Public) Participants (2008)*	*Ratio*
Lifetime Music Lessons or Classes	93.0	34.0	2.7 : 1
Lifetime Visual ArtsLessons or Classes	79.1	17.0	4.7 : 1
Lifetime Acting Lessons or Classes	44.2	5.9	7.5 : 1
Lifetime Dance Lessons or Classes	51.2	12.1	4.2 : 1
Lifetime Creative Writing Lessons or Classes	74.4	11.3	6.6 : 1

Table 5 illustrates the comparative percentages of our sample of STEM graduates with the baseline population (NEA sample). These findings demonstrate that STEM graduates consistently report more lessons in music, visual arts, acting, dance, and creative writing over a lifetime when compared to the general population.

In order to compare the role of crafts, we looked at the percentages of STEM Honors College graduates who participated in craft activities as a mature adult compared to the general public. In order to use comparable measures we included two comparisons. First, we examined the differences between STEM honors grads and the general public using the NEA data. Next, we looked at how many Americans reported woodworking or photography as their hobby, using Census data (U.S. Census Bureau, 2008), compared with STEM honors graduates.

Table 6: Crafts Exposure between STEM Honors College Graduates and NEA Participants

	Percent of STEM Honors College Graduates as Mature Adults	*Percent of NEA Participants (Active Participation 2008)*	*Ratio*
Crafts	62.8	19.1	3.3 : 1
Non-Textile Crafts	32.6	6.0	5.4 : 1

Crafts = Any Pottery/Ceramics, Woodwork, Metal Work, Mechanics, Glass Blowing, Sewing/Knitting/Weaving, and Electronics as a Mature Adult. Non-Textile Crafts = Any Pottery/Ceramics, Woodwork, Metal Work, Mechanics, and Glass Blowing as a Mature Adult

Table 7: Crafts Exposure for STEM Honors College Graduates and the General Public

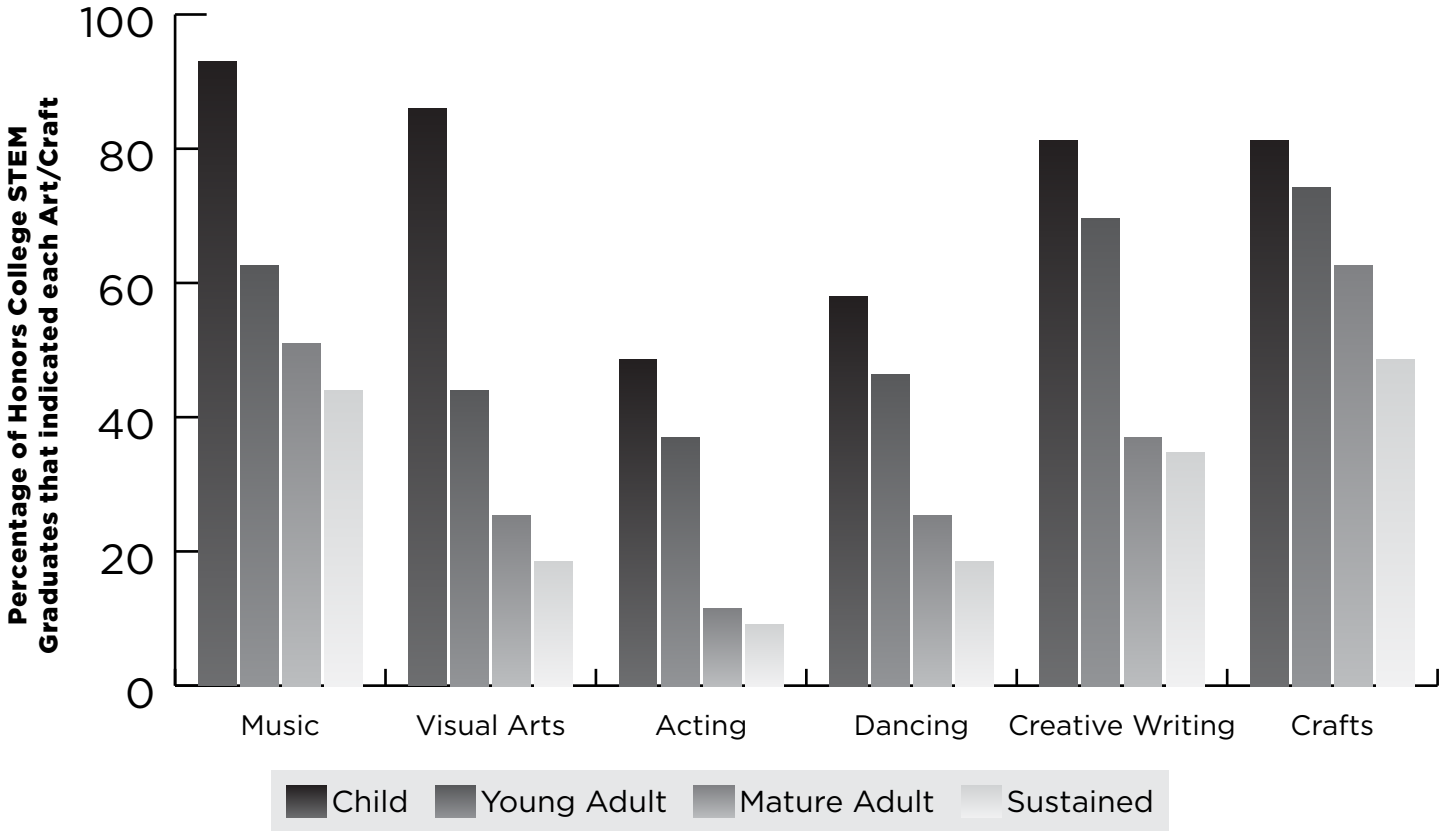
	Percent of STEM Honors College Graduates as Mature Adults	*Percent of Adult Participation in 2008 (Census Data)*	*Ratio*
Photography	93.0	34.0	2.7 : 1
Woodwork	79.1	17.0	4.7 : 1

The data in Tables 5, 6 and 7 demonstrate that MSU STEM honors grads had 3 to 8 times the involvement with various crafts and/or photography at some time during their lives than did the general public. In other words, high achievers in general, and those individuals most likely to found companies and make inventions in particular, have acquired a set of arts and crafts skills to which the average person is never even exposed.

MSU STEM honors grads report 3 to 8 more times involvement in arts and crafts training and practice at some point in their lives than the general public.

In order to address the question of whether there is a particular time at which arts and crafts involvement is particularly important to innovators, we explored when STEM graduates became engaged in various arts and crafts. This analysis looks at both formal and informal involvement. In order to assess formal and informal involvement we calculated the percentage of our total sample who reported music, visual arts, acting, dancing, or writing activities during (1) childhood, (2) young adult, or (3) mature adult phases. We include a sustained arts measure which represents the percentage of STEM graduates who report continuous involvement at every life stage.

Figure 3: Involvement in Arts & Crafts at Different Life Phases



As Figure 3 demonstrates, MSU STEM Honors graduates participated in arts and crafts at all stages of life. Surprisingly, the percentage of STEM Honors graduates who reported sustained participation in each art, which is to say, continuous involvement at each stage of life, is higher for each art than is the percentage of the general public that has had lessons in any of these arts at any single time in their lives (see data in Table 5). In other words, STEM Honors graduates exhibit much higher rates of participation in all arts than does the typical American, and do so persistently throughout their professional lives as well.

MSU STEM honors grads participate in arts and crafts at all stages of life. As a group they sustain participation from childhood through adulthood at higher rates than the overall exposures of the general public.

Figure 3 also shows that young adult and mature participation in arts and crafts by MSU Honors graduates decreases with age. Their very high rates of adult participation in arts and crafts appear to be dependent on the nearly universal exposure by this group of individuals to these arts and crafts as children. The data in Figure 3 also suggest that early exposure to arts and crafts as a child increases the likelihood of participating as a young or mature adult. Further analysis of the data has demonstrated that participation in arts as a young or mature adult is, in fact, largely dependent on childhood participation; see Figures 4 and 5. Although the

percentages vary by the particular art or craft, if one does not participate as a child there is only a 10% chance, on average, of participating in any art or craft as a young adult and only about a 5% chance as a mature adult. After participating in an art or craft as a child, on the other hand, the probability is over 50%, on average, that participation will continue into young adulthood and 25%, on average, into one's mature years.

Figure 4: Likelihood of Participating in Arts and Crafts as a Young Adult as a Function of Childhood Participation

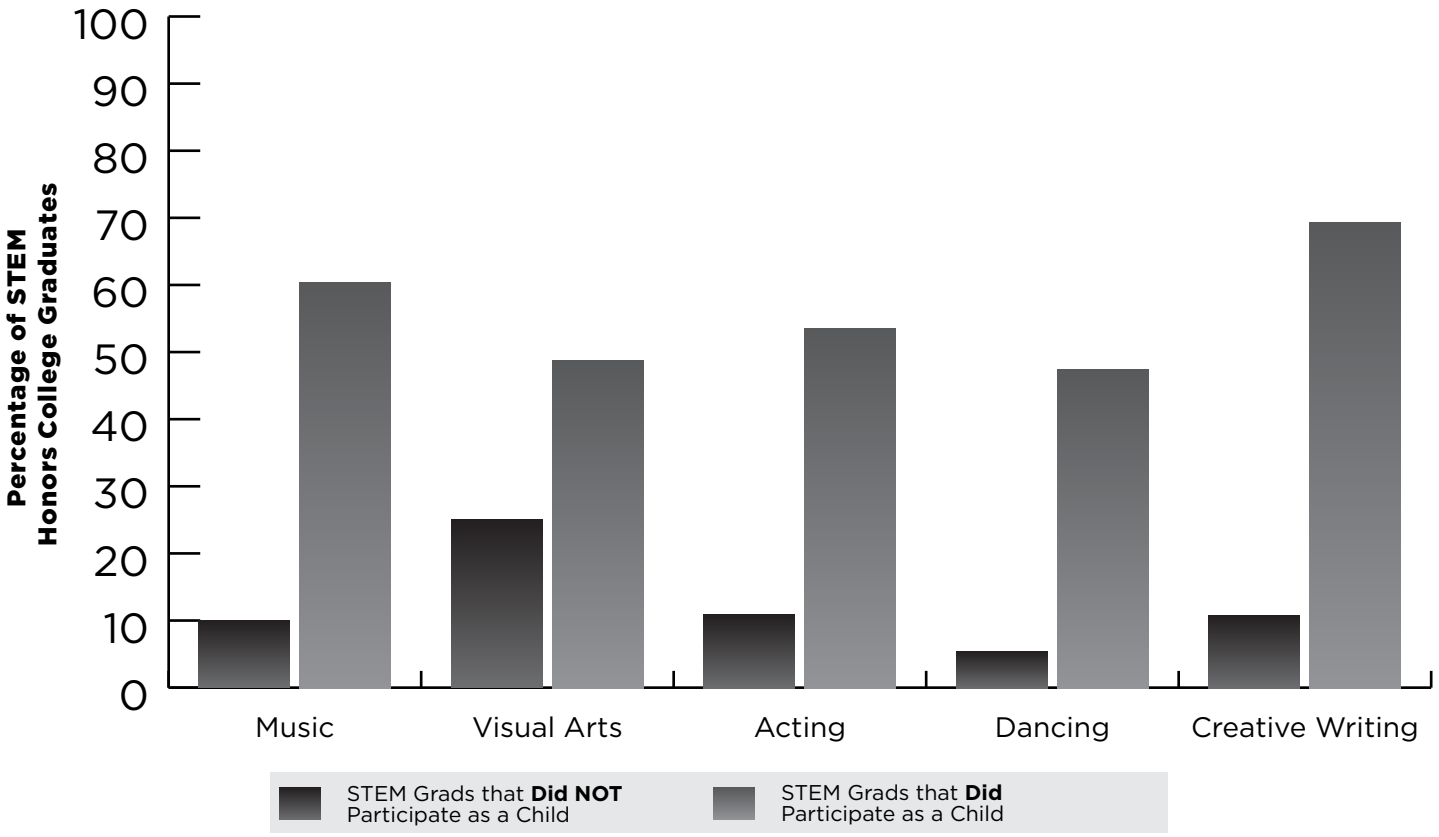
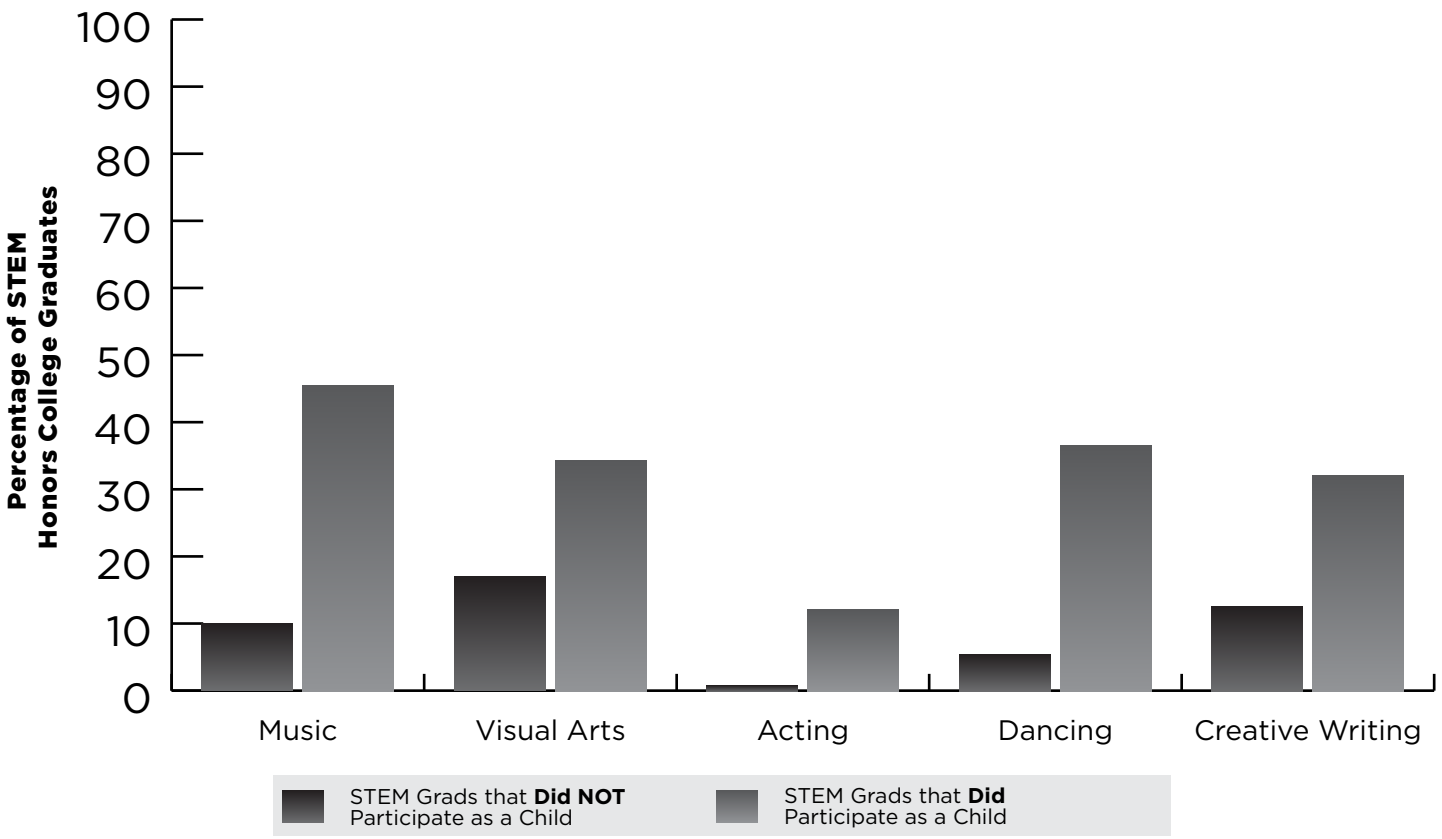


Figure 5: Likelihood of Participating in Arts and Crafts as a Mature Adult as a Function of Childhood Involvement



These data concerning the relationship of young and mature adult participation in arts and crafts to previous participation as a child have very important implications for developing economic capital. If, as we have demonstrated above in Tables 1-4, innovation and entrepreneurship (as measured by patents and companies founded) is directly correlated with a variety of arts and crafts involvement among STEM professionals—and particularly with sustained participation—then providing future STEM professionals with as much arts and crafts exposure as early as possible, and for as long as possible, is an essential component of their education from kindergarten through graduate schooling.

Arts training and participation peaks in childhood, consistently subsiding thereafter; lifetime and sustained practice may thus depend on degree of early exposure.

Recommendations

In sum, we have studied the relationship of arts and crafts training and exposure among STEM professionals from MSU's Honors College with their success in producing patentable inventions and founding new companies. As a group, these STEM professionals participate in arts and crafts at a much higher rate than does the average American. Yet even within this group of highly successful individuals, exposure to a wide variety of arts and crafts differentiated the most entrepreneurial individuals from the rest. Notably, the group as a whole recognized that arts and crafts developed skills and creative ways of thinking that are critical to developing their professional problem solving ability. These self-reported observations were supported by an analysis of the ways they reported solving their technical problems, which included not only logic, but imagination, intuition and play. The vast majority of MSU Honors STEM professionals argued that arts and crafts should be essential components of STEM education. We conclude, therefore, that a very strong case can be made that arts and crafts training correlates significantly with success as a scientist or engineer, and that this success can be measured in economically valuable products such as patentable inventions and the founding of new companies.

These findings suggest that participation throughout an individual's life in art, music, dance, and crafts is a useful, valuable, and essential component of the economic recovery of Michigan and the nation. We therefore recommend that public policy makers:

1. Recognize the utility of arts and crafts in supporting innovation in sciences, technology, engineering and mathematics.

2. Recognize that funding of arts and crafts is a critical component of supporting Michigan's economic transformation.

3. Support research that investigates the most efficient and effective ways to provide arts and crafts exposure throughout the lifespan to foster economic development through innovation.

In order for Michigan to reinvent itself out of the current economic crisis, we must attend to the role of arts and crafts as incubators of creative capacity and generators of innovative capacity.

Appendix A. List of Arts and Crafts

- Drawing
- Painting
- Sculpting
- Pottery/Ceramics
- Photography
- Print Making
- Playing Instrument
- Composing Music
- Singing
- Dancing
- Acting
- Film/Video Making
- Magic
- Woodwork
- Metal Work
- Mechanics
- Glass Blowing
- Sewing/Knitting/Weaving
- Electronics
- Architecture
- Writing Poetry/Fiction
- Nonfiction Writing
- Computer Programming

Appendix B. Tables of Significance

Table B1: Statistically Significant Childhood Arts & Crafts and Creative Capital

Patents

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Pottery/Ceramics	4.2	23.5	3.484	.062
Photography	3.4	33.3	7.079	.008
Woodwork	3.8	26.7	4.626	.031
Metal Work	8.1	50.0	5.916	.015
Mechanics	5.9	42.9	7.411	.006
Electronics	3.1	44.4	11.200	.001
Computer Programming	0	21.7	4.457	.035

Companies

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Metal Work	10.8	50.0	4.438	.035
Electronics	9.4	33.3	3.228	.072
Architecture	12.5	100	5.979	.014

Overall

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Metal Work	13.5	50	3.394	.065

Table B2: Statistically Significant Young Adult Arts and Crafts and Creative Capital

Patents

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Mechanics	6.3	33.3	4.812	.028
Electronics	2.9	66.7	19.476	.000
Architecture	8.1	50.0	5.916	.015
Computer Programming	0	20	3.644	.056

Overall

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Pottery/Ceramics	9.7	40.0	4.910	.027

Table B3: Statistically Significant Mature Adult Arts and Crafts and Creative Capital

Patents

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Print Making	10	100	7.380	.007
Composing Music	7.9	66.7	8.969	.003
Magic	10	100	7.380	.007
Woodwork	6.3	33.3	4.812	.028
Adult Mechanics	7.9	66.7	8.969	.003
Electronics	7.9	66.7	8.969	.003
Architecture	5.9	42.9	7.411	.006

Companies

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Photography	0	26.1	5.501	.019

Overall

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Print Making	15	100	4.979	.026
Composing Music	13.2	66.7	5.623	.018

Table B4: Statistically Significant Sustained Arts and Crafts and Creative Capital

Patents

Art/Craft	*% Not Checked*	*%Checked*	*Chi Square*	*Significance*
Photography	6.1	37.5	5.944	.015
Magic	10.0	100	7.380	.007
Woodwork	5.9	42.9	7.411	.006
Mechanics	7.7	100	15.138	.000
Electronics	7.7	100	15.138	.000
Computer Programming	6.3	33.3	4.812	.028

Companies

Art/Craft	*% Not Checked*	*% Checked*	*Chi Square*	*Significance*
Dancing	9.1	37.5	4.160	.041

Appendix C. Tables of Data for Figures

Figure C1: Cognitive Styles of Professional Problem Solving

Cognitive Styles	% Usage
Exploratory Play	95.3
Logic	95.3
Intuition	79.1
Imagination	81.4
Analogies	81.4

Figure C2: Problem-Solving Environments and Activities

Environment	% Usage
At work	95.3
At home	97.7
On vacation	37.2
Daydreaming	53.5
Falling asleep/waking Up	60.5
Night Dreaming	14.0
Relaxing	30.2
Exercising	55.8
Engaging in hobbies	39.5
In bath/shower	62.8
Meditating	16.3
Other	14.0

Figure C3: Involvement in Arts & Crafts at Different Life Phases

	Child	*Young Adult*	*Mature Adult*	*Sustained*
Music	93	62.8	51.2	44.2
Visual Arts	86	44.2	25.6	18.6
Acting	48.8	37.2	11.6	9.3
Dancing	58.1	46.5	25.6	18.6
Creative Writing	81.4	69.8	37.2	34.9
Crafts	81.4	74.4	62.8	48.8

Figure C4: Likelihood of Participating in Arts and Crafts as a Young Adult as a Function of Childhood Participation

Art/Craft	*STEM Grads that Did NOT Participate as a Child (%)*	*STEM Grads that Did Participate as a Child (%)*	*Ratio*
Music	10.0	60.6	1 : 6
Visual Arts	25.0	48.9	1 : 1.9
Acting	11.0	53.7	1 : 4.8
Dancing	5.6	47.6	1 : 8.5
Creative Writing	10.9	69.5	1 : 6.4

Figure C5: Likelihood of Participating in Arts and Crafts as a Mature Adult as a Function of Childhood Involvement

Art/Craft	*STEM Grads that Did NOT Participate as a Child (%)*	*STEM Grads that Did Participate as a Child (%)*	*Ratio*
Music	10.0	45.7	1 : 4.6
Visual Arts	17.0	34.4	1 : 2
Acting	1.0	12.2	1 : 12.2
Dancing	5.6	36.7	1 : 6.6
Creative Writing	12.7	32.2	1 : 2.5

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