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Rex LaMore, Robert Root-Bernstein, Michele Root-Bernstein, John H. Schweitzer, James L. Lawton, Eileen Roraback, Amber Peruski, Megan VanDyke and Laleah Fernandez

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What is This?

# Arts and Crafts: Critical to Economic Innovation

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## Abstract

Governments, schools, and other nonprofit organizations are engaged in critical budget decisions that may affect our economic development success. The assumption is that arts and crafts are dispensable extras. Research suggests, however, that disposing of arts and crafts may have negative consequences for the country's ability to produce innovative scientists and engineers who invent patentable products and found new companies. A study of Michigan State University Honors College science and technology graduates (1990-1995) yielded four striking results: (a) graduates majoring in *science, technology, engineering, and mathematics* (STEM) subjects are far more likely to have extensive arts and crafts skills than the average American; (b) arts and crafts experiences are significantly correlated with producing patentable inventions and founding new companies; (c) the majority believe that their innovative ability is stimulated by their arts and crafts knowledge; and (d) lifelong participation and exposure in the arts and crafts yields the most significant impacts for innovators and entrepreneurs.

## Keywords

arts, STEM, innovation, creativity

## 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. To remain competitive in the global knowledge economy, communities must make available arts and crafts opportunities to foster creativity and innovation that will drive the formation of highly skilled, well-paying jobs, as well as offer new commodities and services.

A community's creative and cultural assets have potentially three primary effects. First, a thriving arts sector functions as a direct jobs generator with direct economic benefits. Cultural assets, including art museums, orchestras, theaters, galleries, and ongoing arts education opportunities, serve as sources of jobs for personnel in the arts. 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). It is this less understood relationship between arts and crafts participation by individuals and patents generated and businesses formed that was the focus of this research. 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.

## The Knowledge Economy: Policy Relevance of the Research

At present, public policy decisions often decrease or eliminate funding for the arts and cultural assets of communities, assuming that they are expendable "extras" in a time of economic downturn. This may be a serious economic development policy error based on a set of false assumptions. Without clear knowledge of the arts' role in building general creative capacity in individuals, the long-term costs of this approach cannot be adequately assessed. Funding reductions may inadvertently stifle the technology-inventing capacity of current and future generations. This reduced capacity for invention, along with a weakening of the cultural environment necessary

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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.

Emerging critical research suggests that the local and regional development of innovative science and technology 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 (Root-Bernstein, Bernstein, & Garnier, 1995).

In 2002, social scientist Richard Florida changed the economic development paradigm by introducing the concept of the creative class and proposing 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 that support the arts will attract and retain the creative class and consequently enjoy higher levels of economic prosperity.

Child researchers suggest that exposure to arts can develop creative potential in young children (Western Michigan University Research Foundation & EPIC-MRA, 2005). Creative potential in turn enhances problem-solving and critical-thinking skills essential to success in an information- and innovation-based economy. For example, in 2010 students with 4 years of arts or music classes in high school and AP/Honors courses scored higher on the Standardized Aptitude Test (SAT). These students scored an average of about 68 additional points on reading and 57 points on math. (see, e.g., College Board and the National Merit Scholarship Corporation, 2010). Longitudinal studies by Catterall et al. report not only that SAT scores improve, but all academic outcomes, especially in at-risk students (Catterall, Dumais, Hampdon-Thompson, 2012).

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 et al. (1995, 2008; 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 by awards such as the Nobel Prize. Root-Bernstein, Bernstein, Gamier (1993); Root-Bernstein et al. (1995); Root-Bernstein et al. (2008); and Root-Bernstein and Root-Bernstein (2004) 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 4,406 members of the Sigma Xi Scientific Research Society,<sup>1</sup> Nobel laureates were at least 15 (and as much as 35) times more likely to have arts or crafts avocation as an adult (Root-Bernstein et al., 2008).

Thus far, however, there have been no formal studies of the role that arts may play in stimulating, nurturing, or creating creative capacity among inventors and entrepreneurs as



measured by such critical economic development indicators as patents generated or businesses formed particularly among (science, technology, engineering, and math) STEM majors. Our study examines the formal and informal arts and crafts training of scientists, technologists, engineers, and mathematicians to determine what type of arts exposure, at what stage, influences their economic development impacts.

## Research Methods

To test this art-science/economic development connection, the research project investigated the *artsmajors* of Michigan State University (MSU) Honors College graduates from the years 1990 to 1995 who majored in science, technology, engineering, or mathematics. Respondents had majors in natural sciences, such as zoology, chemistry, and physiology, and in social sciences, such as psychology and economics, among others. Almost all respondents had received advanced degrees and worked in professions varying from professor to graphic designer to software engineer. The advantage of studying this group is that all survey participants 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 impacts of variables other than arts and crafts participation are thus reduced; however, drawbacks include self-selection bias that may have caused the results to be unrepresentative of the general public. 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 crafts increases individual innovative capital. We further hypothesize that sustained training or involvement in the arts can predict professional success in science and technology.

A web-based survey was sent out using email to MSU Honors College graduates who earned degrees between 1990 and 1995. The Honors College at MSU 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. Admission into the college is

based on a student's GPA, standardized testing scores, and high achievements in high school education.

Our sample included 270 individuals with a valid email address.<sup>2</sup> 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 undergraduate majors. STEM undergraduate majors included science, technology, engineering, and mathematics. Of the 82 responses, 44 were identified as STEM majors. Of the 44 identified as STEM majors, 36.6% identified themselves as male and 63.4% identified themselves as female. All respondents were within the ages of 35 and 44, and 95.1% identified themselves as Caucasian, 2.4% identified themselves as Asian/Pacific Islander, and 2.4% identified themselves as Multiracial.

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; and *mature adult*, 25 years of age and older. 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. Participants indicated with which arts or hobbies they were involved. 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 focused on patents generated and companies formed 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, labeled as "Overall" in the following tables, we investigated whether any arts or crafts were associated with total creative capital as measured by an



**Table 1.** Difference in Percentage of Childhood Participation Between Individuals Who Have and Do Not Have Patents, Companies, and Overall Creative Capital.

Art/Craft	Patents	Companies	Overall
Pottery/ceramics	18.3 <sup>a</sup>		
Photography	29.9 <sup>c</sup>		
Woodwork	18.9 <sup>b</sup>		
Metal work	41.9 <sup>b</sup>	39.2 <sup>b</sup>	36.5 <sup>a</sup>
Mechanics	37.0 <sup>c</sup>		
Electronics	41.3 <sup>c</sup>	23.9 <sup>a</sup>	
Architecture		87.5 <sup>b</sup>	
Computer programming	21.7 <sup>b</sup>		

Source. Authors' calculations.

a. Statistically significant at the .1 level.

b. Statistically significant at the .05 level.

c. Statistically significant at the .01 level.

**Table 2.** Difference in Percentage of Young Adult Participation Between Individuals Who Have and Do Not Have Patents, Companies, and Overall Creative Capital.

Art/Craft	Patents	Companies	Overall
Pottery/ceramics			30.3 <sup>b</sup>
Mechanics	27.0 <sup>b</sup>		
Electronics	63.8 <sup>c</sup>		
Architecture	41.9 <sup>b</sup>		
Computer programming	20.0 <sup>a</sup>		

Source. Authors' calculations.

a. Statistically significant at the .1 level.

b. Statistically significant at the .05 level.

c. Statistically significant at the .01 level.

aggregate of all peer-reviewed publications, books, patents, or companies. Our reasoning is that those with the highest number production of publications, books, patents, or companies produce the most creative capital. This latter investigation compared the most creative 10% of the respondents with 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 produce a small fraction of the total output, whereas a small minority of participants produces the vast majority of the output (Pareto & Page, 1971).

In general, STEM Honors College graduates who have founded companies or produced patents have higher than average participation in some arts and many crafts than do STEM Honors College graduates who have not found companies or patented inventions. The relationship between arts and crafts involvement and creative capital was mostly positive across the life span, but specific arts and crafts were found to be statistically significant at certain ages. Tables 1 to 4 display the significant differences in proportion between those STEM Honors College graduates who had patents,

**Table 3.** Difference in Percentage of Mature Adult Participation Between Individuals Who Have and Do Not Have Patents, Companies, and Overall Creative Capital.

Art/Craft	Patents	Companies	Overall
Photography		26.1 <sup>b</sup>	
Print making	90.0 <sup>c</sup>		85.0 <sup>b</sup>
Composing music	58.8 <sup>c</sup>		53.5 <sup>b</sup>
Magic	90.0 <sup>c</sup>		
Woodwork	27.0 <sup>b</sup>		
Mechanics	58.8 <sup>c</sup>		
Electronics	58.8 <sup>c</sup>		
Architecture	37.0 <sup>c</sup>		

Source. Authors' calculations.

a. Statistically significant at the .1 level.

b. Statistically significant at the .05 level.

c. Statistically significant at the .01 level.

companies, and overall creativity and those who did not. Differences in proportions that were not significant were not included in the tables.

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). Table 1 illustrates the relationship between participation in crafts and arts 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 for pleasure 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). 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 (see below).

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

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 mature adult was related to companies founded (see Table 3).



**Table 4.** Difference in Percentage of Sustained Participation Between Individuals Who Have and Do Not Have Patents, Companies, and Overall Creative Capital.

Art/Craft	Patents	Companies	Overall
Photography	31.4 <sup>b</sup>		
Dancing		28.4 <sup>b</sup>	
Magic	90.0 <sup>c</sup>		
Woodwork	37.0 <sup>c</sup>		
Mechanics	92.3 <sup>c</sup>		
Electronics	92.3 <sup>c</sup>		
Computer programming	27.0 <sup>b</sup>		

Source. Authors' calculations.

a. Statistically significant at the .1 level.

b. Statistically significant at the .05 level.

c. Statistically significant at the .01 level.

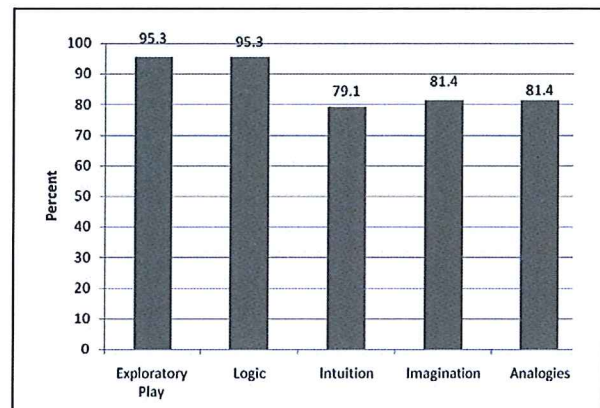
Finally, we looked at which activities, if sustained over the respondents' life spans, correlate with patents, companies, and overall creativity. Sustained activities are those that are practiced at every stage of life from childhood through mature adulthood. Here the data suggest that ongoing involvement 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 to be involved in a sustained manner with one or more crafts or arts such as music composition, dance, or photography. Our findings suggest that long-term experience with the creative process in arts and crafts may enhance creative potential in science and technology.

These findings indicate that participation in various arts and crafts positively 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. We specifically examined STEM students because of the general perception that these students are likely to be the primary source of invented products. This is also the academic discipline where scientific professionals are most prevalent. Although causality cannot be determined by this analysis, these 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 addition to empirically testing for a relationship between arts and crafts activities and innovation, we asked all Honors



**Figure 1.** Cognitive styles of professional problem solving.

STEM respondents to comment on their perception of the existence of this relationship. We asked the following question: "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." Out of 36 respondents, 58.3% responded with "Yes/Certainly," 13.9% responded "Maybe," and 27.8% responded "No."

As well as interviewing the STEM professionals about the relationship of arts and crafts skills to their professional work, we also asked them to identify (through a multiple-choice question that allowed for multiple responses) what types of cognitive tools they use for problem solving. These tools included obviously scientific ones such as "logic"—they also included ones that are more often associated with artistic thinking, such as the use of "analogies," "playing," "intuition," and "imagination." The results are shown in Figure 1.

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 fields of science and engineering, an overwhelming majority also reported using "artistic" styles of thinking: 95.3% 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.

### Do Inventors and Entrepreneurs Report Higher Than Average Arts Experience?

Finally, to examine the amount of arts and crafts exposure STEM professionals get as compared with the average individual, we compared the STEM Honors College graduates with the general public. Statistics involving the average arts

**Table 5.** Comparison of STEM Graduates to NEA Participants.

	Percentage of STEM Honors College Graduates	Percentage of NEA (General Public) Participants (2008)	Ratio
Lifetime music lessons or classes	93.0	34.0	2.7:1
Lifetime visual arts lessons 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

Note. STEM = science, technology, engineering, and mathematics; NEA = National Endowment of the Arts.

Source. Authors' calculations.

**Table 6.** Crafts Exposure Between STEM Honors College Graduates and NEA Participants.

	Percentage of STEM Honors College Graduates as Mature Adults	Percentage of NEA Participants (Active Participation 2008)	Ratio
Crafts <sup>a</sup>	62.8	19.1	3.3:1
Non-textile crafts <sup>b</sup>	32.6	6.0	5.4:1

Note. STEM = science, technology, engineering, and mathematics; NEA = National Endowment of the Arts.

a. Crafts = any pottery/ceramics, woodwork, metal work, mechanics, glass blowing, sewing/knitting/weaving, and electronics as a mature adult.

b. Non-textile Crafts = any pottery/ceramics, woodwork, metal work, mechanics, and glass blowing as a mature adult.

Source. Authors' calculations.

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

	Percentage of STEM Honors College Graduates as Mature Adults	Percentage of Adult Participation in 2008 (Census Data)	Ratio
Photography	54.8	12.7	4.3:1
Woodwork	21.4	4.4	4.9:1

Note. STEM = science, technology, engineering, and mathematics.

Source. Authors' calculations.

experiences of American adults were made available through the National Endowment of the Arts (NEA). This group 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 to compare the levels of arts between STEM graduates and the general population.

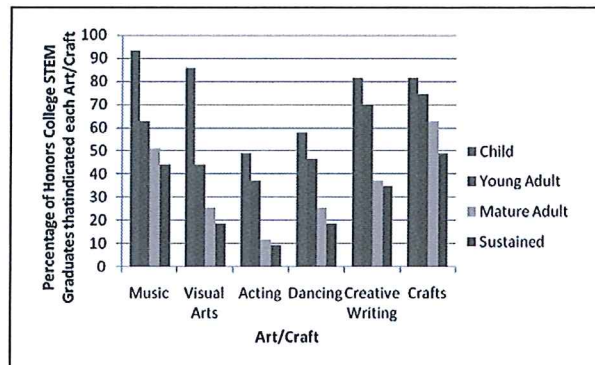
Table 5 illustrates the comparative percentages of our sample of STEM graduates with the baseline population (NEA sample). For this analysis, we compared the percentage of the general public who report taking any music lessons with the percentage of STEM graduates who indicated taking lessons or having 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 lives. These findings demonstrate that STEM graduates consistently report more lessons in music, visual arts, acting, dance, and creative writing over a lifetime when compared with the general population.

To compare the role of crafts, we looked at the percentages of STEM Honors College graduates who participate in craft activities as a mature adult compared with the general public. To use comparable measures, we included two comparisons. First, we examined the differences between STEM Honors College graduates and the general public using the NEA data. Next, we looked at how many Americans report a woodwork and photography hobby (using 2008 Census data [<http://www.census.gov/>]) compared with STEM Honors College graduates.

The data in Tables 5, 6, and 7 demonstrate that MSU STEM Honors College graduates have three to eight times the involvement with various crafts and with photography at





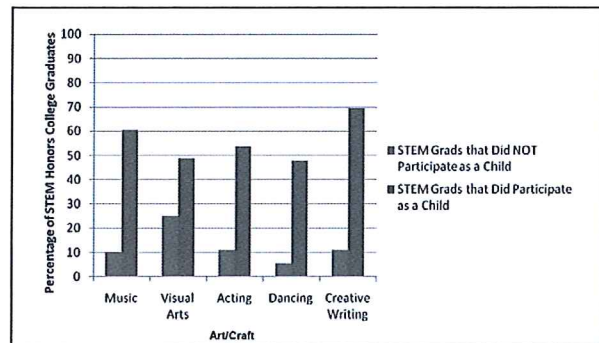
**Figure 2.** Involvement in arts and crafts at different life phases.

some time during their lives than does 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.

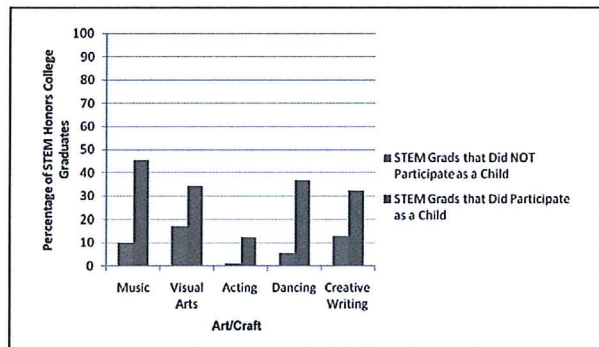
To address the question of whether there is a particular time at which arts and crafts involvement is particularly important to innovators, we explored *when* STEM Honors College graduates became engaged in various arts and crafts. This analysis looks at both formal and informal involvement. To assess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

As Figure 2 indicates, although MSU STEM Honors College graduates participated in arts and crafts at all stages of life, we observe, however, a consistent decline in rates of participation from childhood to mature adulthood. Their higher 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 2 also suggest that early exposure to arts and crafts as a child increases the likelihood of participating as a young or mature adult.

Analysis of the data in Figures 3 and 4 indicates that participation in arts as a young or mature adult is, in fact, largely dependent on childhood participation. 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 3.** Likelihood of participating in arts and crafts as a young adult as a function of childhood participation.



**Figure 4.** 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 creative capital. If, as we have demonstrated above in Tables 1 to 4, innovation and entrepreneurship (as measured by patents and companies founded) is 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 children, and for as long as possible (young adult to mature adult), may be an essential component to their creative capital potential.

## Conclusions

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 an engineer and that this success can be measured in economically valuable products such as patentable inventions and the founding of new companies.

However, we note that in this seminal research that a potential self-selection bias may exist. This bias is possibly evident in the individuals who are admitted to the MSU Honors College and those who responded to the survey. This possibility of a study bias may affect the results in two identifiable ways.

1. The MSU Honors College students are, by their admission into the college, recognized to be higher than average scholastic achievers.
2. As "scholastically high achievers" they may not represent the general public.

The second bias may be the appeal of this research to those who are engaged in arts and crafts thus skewing the data in that regard. We note these possible biases and encourage even further studies of broader populations to test this seminal research hypothesis.

For the country to reinvent itself out of the recent economic crisis, we must attend to the role of arts and crafts as incubators and generators of innovative and creative capacity. If the goal is to generate jobs, there needs to be innovators that are capable of producing creative products, solutions, and processes. To produce these innovators, STEM individuals need to be exposed to arts and crafts throughout their life span. In short,

STEM + Arts and Crafts = Innovators → Jobs

Not only do individuals need to be exposed to arts and crafts, the exposure needs to be sustained throughout the life span. Arts and crafts opportunities need to be present to individuals at all ages. Successful economic development in the globally competitive world calls on policy makers and practitioners to consider a variety of factors that affect individual, entrepreneurial, and community success. Providing arts and

cultural experiences to children, young adults, and mature adults may be critical in securing a region's creative capital.

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### Notes

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 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.
2. Of the 298 invitations, 28 emails were invalid.

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