Does Playing the Violin Help Science Students Become Better Scientists?

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ABSTRACT

It is believed that art and scientific research are two of the most creative-oriented areas. Will scientific research benefit from arts instruction? The purpose of this paper is to explore the relationship between arts instruction and scientific research performance of science and engineering students in universities.

This paper uses experimental methods. The students with arts instruction are in the experimental group and the students without arts instruction are in the control group. Based on secondary research, we designed the measurement scales and questionnaires of creative personality and scientific research performance. We distributed 302 questionnaires in universities and 204 valid questionnaires were collected, all of which were completed by postgraduates.

We analyzed the questionnaires retrieved by conducting independent sample tests to examine whether there were significant differences in scientific research performance and creative personality between the experimental group and the control group. And in the experimental group, we investigated whether creative personality has a significant effect on scientific research performance.

After the empirical analysis, we did not find that arts instruction has a significant effect on scientific research performance directly. However, we found that arts instruction influences creative personality, and thus affects scientific research performance. Creative personality plays an intermediary role between arts instruction and scientific research performance.

INTRODUCTION

Albert Einstein, as is well known, was one of the greatest scientists who developed two of the most important theories in physics: the special theory and general theory of relativity [1]. Apparently, he was one of the most creative persons in the world. For a long time, many people have been wondering where his creativity came from. Some people believe that one of the answers is music. When Einstein was about five years old, his mother arranged for him to take violin lessons. Music was no mere diversion for him. The violin proved useful during the years he lived alone in Berlin, wrestling with general relativity. "Whenever he felt that he had come to the end of the road or faced a difficult challenge in his work," said his son Hans Albert, "he would take refuge in music and that would solve all his difficulties [1]." Though Einstein never became a professional violinist, it is believed that art made him more creative.

Another famous example is Leonardo da Vinci, who is widely considered as one of the greatest painters of all time. He started his art career in his teens. When he was 14 years old, he became an apprentice in a workshop in Florence and remained in training in painting and sculpture for six years [2]. Apart from art, his areas of interest included mathematics, engineering, anatomy, geology, astronomy, botany, paleontology and cartography. The scope and depth of his interests were without precedent in recorded history. Thus, he is widely considered one of the most diversely talented individuals ever to have lived.

Based on these two examples, it seems there is some connection between arts instruction and creativity. At least many Chinese parents believe this connection exists. Nowadays more and more Chinese parents are sending their children to art trainings. They do not expect their children to be artists when they grow up, but they do believe that art could help the children develop a creativity mindset for their future. Given widespread participation in arts, it is natural to ask if the arts instruction could cultivate creativity of human beings.

It is believed that art and scientific research are two of the most creatively-oriented areas. Will scientific research benefit from arts instruction? The purpose of this paper is to explore the relationship between arts instruction and scientific research performance of science and engineering students in universities.

THEORETICAL BASIS

One of the most controversial issues in the field of creativity research is whether creativity is domain-general or domain-specific.

Domain generality indicates that creativity is a kind of common feature and ability across domains. Highly creative people from different domains have the same or similar creative personality, and they have shown the same or similar cognition processing mechanism during creative problem-solving processes [3]. In contrast, domain specificity indicates that individuals who have shown high creativity in a certain domain don't necessarily show high creativity in other domains. The evidence of domain specificity is correlation coefficient between creativities across domains. The most commonly-used method of assessing individual's creativity is Consensus Assessment Technique (CAT). To ensure authority of results, the key of CAT is to engage experts of corresponding domains to evaluate individual's creative works [4]. Much research using CAT has shown that the correlations between creativity across different domains are low or even zero [5]. For instance, someone whose painting is very creative does not show any creativity in poetry.

To combine generality and specificity, Baer and Kaufman [6] invented the Amusement Park Theoretical (APT) model of creativity. The APT model uses the metaphor of an amusement park to describe creativity. It contains four levels, which are initial requirements, general thematic areas, domains and micro-domains.

The first level is initial requirements, which are essentially the requirements for all creative work, as, for example, you need a ticket in order to go to an amusement park. According to Baer and Kaufman, initial requirements, which are domain general, include intelligence, motivation and environment. The next level is general thematic areas in which someone could be creative (e.g., the arts, science, etc.). This level is the equivalent of deciding which type of amusement park to visit (e.g., a water park or a zoo). The next two levels are more domain specific. The third level is domains. For example, there are music, dancing, painting, and several others within arts, as there are reptile house, bird house and mammal house in a zoo. The fourth level is micro-domains. For instance, musical genres include classical music, jazz, blues and so on. This level is the equivalent of choosing one type of animal in a reptile house.

The APT model could explain the mechanism of creativity more comprehensively than domain generality or domain specificity theories. In the APT model, the first level is domain-general and the next three levels are more and more domain-specific. However, there are only three elements mentioned as initial requirements in the current APT model. Is it possible that creative personality is also one of the initial requirements? This paper is to investigate if creative personality could bridge arts instruction and scientific research performance.

RESEARCH HYPOTHESIS

This paper has measured scientific research performance in two dimensions: scientific research outcome performance, which is easy to quantify; and scientific research work performance, which is valuable to scientific research but hard to quantify, to make the result more comprehensive. Scientific research outcome performance in this paper is the assessment of an individual's all scientific research outcome and it is mainly to evaluate quantity, level and other factors of academic achievements. Scientific research work performance in this paper is the assessment of an individual's scientific research process, and it is mainly to test the performance of work completion, interpersonal relationship handling, and work devotion by self-assessment. Therefore, there are four main variables in this research: arts instruction, creative personality, scientific research outcome performance, and scientific research work performance.

There is some previous research about the relationship between arts instruction and science learning. Vaughn and Winner [7] found that, for the students who had taken an arts course, their mathematics scores in SAT were higher than those who had not taken any in high school; and for the students who had taken an arts course for four or more years, their scores were higher than those who had taken an arts course for less than four years. Muhammad [8] took Nigerian primary school students as samples, finding there was significant correlation between their performance of “cultural and creative art” and “basic science and technology”. Based on the previous research, here are the hypotheses about the relationship between arts instruction and scientific research performance.

H1: There are significant differences in scientific research outcome performance between students with and without arts instruction.
H2: There are significant differences in scientific research work performance between students with and without arts instruction.

Previous research has shown that arts education plays an important role in brain development. It can accelerate the development of visual cognition system and the balance of the brain, and then promote creative thinking and creative personality [9]. As is mentioned above, openness is one of the features of creative personality. Openness not only makes individuals learn new things better, but also encourages individuals to conduct creative activities [10]. Some other research has indicated that creative talents from most domains have shown their above-average openness. Wolfradt and Pretz [11] took university students from different subjects as respondents, finding there was significant positive correlation between openness and creativity. Whether the students majored in natural science or arts, those who got higher scores for openness were more creative. Based on the previous research, here are the hypotheses about creative personality.

H3: There are significant differences in creative personality between students with and without arts instruction.

H4: Creative personality has a significant effect on science and engineering students' scientific research outcome performance.

H5: Creative personality has a significant effect on science and engineering students' scientific research work performance.

All the hypotheses can be depicted in the figure below.

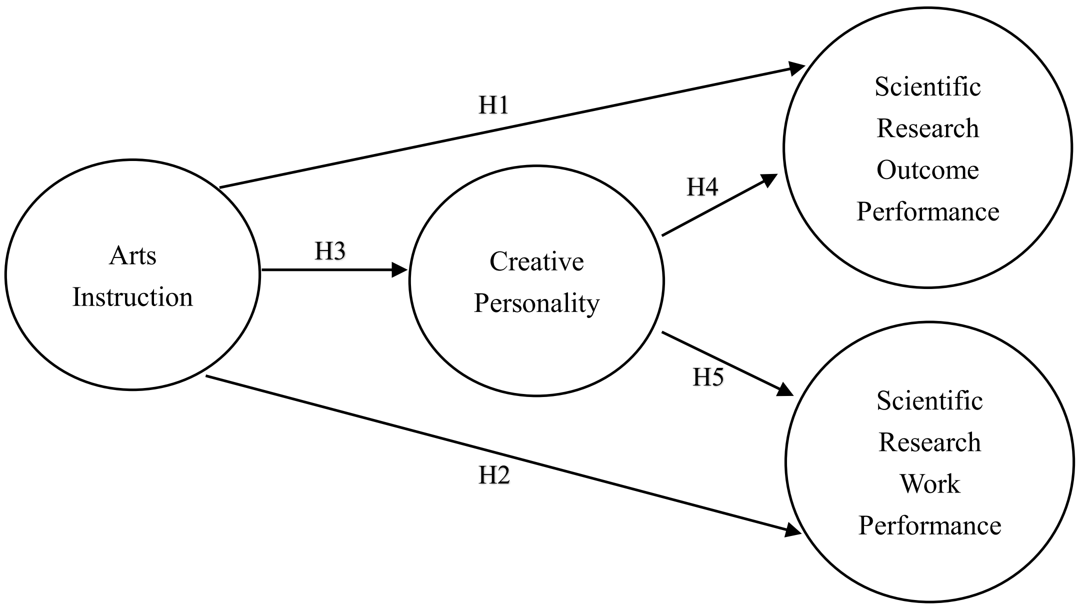

Figure 1 Model of Research Hypotheses

QUESTIONNAIRE DESIGN

The purpose of this research is to explore the relationship between arts instruction and scientific research performance of science and engineering students in universities.

According to the subject catalogue published by the Ministry of Education of China, there are 14 subjects in science and 38 subjects in engineering. Respondents are science and engineering students, meaning they all majored in these subjects.

All the respondents answered the same questionnaire. There were four parts in the questionnaire. The first part is personal basic information including gender, age, educational background, hometown, parents' professions, and parents' educational background.

The second part is about arts instruction. All respondents need to answer whether they have taken continuous (at least more than 1 year without interruption) systematic art trainings. If not, they will be classified as being in the control group and they can skip the rest of this part; if yes, they will be classified as being in the experimental group and they are required to answer when they took arts trainings and what kind of certificates or prizes they were awarded.

The third part of the questionnaire is about creative personality. Creative personality refers to the personality traits strongly associated with individual creativity. The framework of creative personality that this paper used was introduced by Williams [12], [13]. In this framework, creative personality can be classified into four dimensions: curiosity, risk taking, complexity, and imagination. Here are the connotations of all dimensions in this paper.

Curiosity: [being willing to] keep an open mind to confusing questions; like learning unknown things, wanting to figure things out; considering problems, having many thoughts.

Risk Taking: [having courage to] dare to face risk and failure; daring to make a plan and take responsibilities under the condition of lacking clear rules or procedures; daring to defend their own ideas.

Complexity: [being challenged to be] adept in searching for a variety of solutions; in figuring out a clear path in a chaotic situation; and in researching complicated questions.

Imagination: [having the power to be] adept in visualizing abstract descriptions; fantasizing over things that never happened; tending to judge by intuition.

This paper used the items from “Williams Creativity Assessment Packet” [14] to test creative personality. There are 50 items from four dimensions introduced above in “Williams Creativity Assessment Packet”. Considering the questionnaire length, we chose 4 items with high reliability and validity from each dimension, giving us a scale of creative personality with 16 items.

Table 1. Items of Creative Personality

Variable	Dimensions	Items
creative personality	Complexity	(1) If things cannot be done the first time, I will keep trying until I make it. (2) When I am searching for solutions, I feel very excited. (3) I like to solve problems, even if the right answer doesn’t exist. (4) I like distinctive things.
	Curiosity	(5) I like to do a lot of new things. (6) When I am doing something, I tend to refer to different information to get a comprehensive understanding. (7) When I am painting, I like to change colors and shapes. (8) I am interested in machines, and I would like to know what is inside and how they work.
	Imagination	(9) I would like to think about things that will not happen to me. (10) I like to imagine that I will become an artist, musician or poet one day. (11) I like to think about some new ideas even if they will not be used. (12) When I see a photo of a stranger, I like to guess

		what kind of person he is.
	Risk Taking	(13) I don't like too many restrictive rules. (14) I like to sing new songs nobody knows. (15) I like to make new things by myself. (16) I like to try new things just to know what will happen.

For each question, respondents can select "Almost Never True", "Usually Not True", "Occasionally True", "Usually True", "Almost Always True", and accordingly, the score is 1, 2, 3, 4, 5. Therefore, we can get the score of creative personality.

The fourth part is scientific research performance. We interviewed some potential respondents in pilot studies, learning that (1) very few of them have published books; (2) few of them have got international patents; (3) almost none of them has published more than 4 papers in SCI journal. Based on this information, we finalized the questions for testing scientific research outcome performance.

Table 2 Items of Scientific Research Outcome Performance

Variable	Dimensions	Items
Scientific Research Outcome Performance	Papers	(1) number of papers published in SCI journals (as the first or second author) (2) number of papers published in EI journals (as the first or second author) (3) number of papers published in domestic core journals (as the first or second author) (4) number of papers published in international academic conferences (as the first or second author) (5) number of papers published in domestic academic conferences (as the first or second author)
	Patents	(6) number of domestic patents

For item (1), there are 5 options, "0", "1", "2", "3", "4 or more than 4", and accordingly the score is 0, 6, 12, 18, 24; for item (2), there are 5 options, "0", "1", "2", "3", "4 or more than 4", and accordingly the score is 0, 2, 4, 6, 8; for item (3), there are 5 options, "0", "1-2", "3-5", "6-8", "9 or more than 9", and accordingly the score is 0, 1, 2, 3, 4; for item (4), there are 5 options, “0”, “1”, “2”, “3”, “4 or more than 4”, and accordingly the score is 0, 2, 4, 6, 8; for item (5), there are 5 options, “0”, “1-2”, “3-5”, “6-8”, “9 or more than 9”, and accordingly the score is 0, 1, 2, 3, 4; for item (6), there are 5 options, “0”, “1”, “2”, “3”, “4 or more than 4”, and accordingly the score is 0, 1, 2, 3, 4. The sum of all these scores is the result of scientific research outcome performance test.

We finalized the items for testing scientific research work performance by referring to Van Scotter and Motowidlo’s performance scale [15] designed for testing university teachers’ scientific research performance.

Table 3 Items of Scientific Research Work Performance

Variable	Dimensions	Items
Scientific Research Work Performance	Work Completion	(1) I can always complete scientific research work efficiently. (2) The quality of my scientific research work has been maintained at a high standard and the effect of my work has been recognized by all. (3) In scientific research, I can always succeed in achieving the goal of the plan. (4) I am one of the best members of the team or the lab.
	Interpersonal Relationship Handling	(5) In scientific research, I can lead or coordinate other team members to complete scientific research tasks. (6) I will support and encourage my classmates when they encounter difficulties. (7) I can communicate effectively with my supervisor and other members of the research team about the research work.
	Work Devotion	(8) I like to seek challenging jobs and I am willing to take on more work. (9) Sometimes I do scientific research at rest time to ensure the task is completed on time. (10) I can take the initiative to complete difficult work enthusiastically.

For each item, respondents can select “Almost Never True”, “Usually Not True”, “Occasionally True”, “Usually True”, “Almost Always True”, and accordingly, the score is 1, 2, 3, 4, 5. Thus, we can get the score of scientific research work performance.

DATA

Considering that undergraduate students are mainly learning professional knowledge without scientific research outcomes, all the respondents in this paper are postgraduate students studying for Master’s degree or Doctorates.

To ensure the objectivity of the research, we conducted random sampling to collect data. We distributed questionnaires in both online and offline. We distributed questionnaires via QQ, Wechat and Weibo online. We also invited some members of art associations in universities to help us to distribute questionnaires, because there were some science and engineering students with arts instruction in these art associations.

In total, we distributed 302 questionnaires and we received 251. The response rate was 83.1%. We examined all the completed questionnaires we had received. Eventually, there were 59 valid completed questionnaires of the experimental group and 145 of the control group.

We used SPSS 20.0 for data analysis. Here are the procedures.

(1) Use Nonparametric tests - Two independent sample tests to process the basic information of the experimental group and the control group. The purpose was to ensure there was no significant difference between these two groups of data from the perspective of demography.
(2) Use Cronbach Alpha to analyze reliability.
(3) Use KMO and Bartlett’s test to ensure the data is suitable for Factor Analysis.

(4) Use Nonparametric tests - Two independent sample tests to test whether there is significant difference in scientific research performance and creative personality between the experimental group and the control group.
(5) Use one-way ANOVA to test whether creative personality has significantly affected scientific research performance.
(6) Hypothesis testing.

To ensure there is no significant difference between these two groups (experimental group and control group) of data from the perspective of demography, we used Nonparametric tests - Two independent sample tests to process the basic information (age, degree, subject) of the experimental group and the control group.

Table 4 Independent Sample Tests Result in Demographic Variables

	Mann-Whitney U	Wilcoxon W	Z	Asymptotic Significance (2-sided)
Gender	3490.000	14525.000	-1.057	.290
Age	4260.000	6030.000	-.062	.951
Degree	3704.000	14289.000	-1.844	.065
Subject	3881.500	14466.500	-1.410	.159

As we can see from the result, the asymptotic significance in terms of age, degree, subject between experimental group and control group is greater than 0.05, therefore there is no demographically significant difference between these two groups' data.

There are four variables in this research. Arts instruction is an exhaustive variable applying nominal measures. The reliability and validity of the other three variables need to be analyzed. This research used Cronbach Alpha to analyze reliability.

Table 5 Reliability Analysis of variables

Variable	Measurement Item	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Overall Cronbach's Alpha
Creative Personality	CP1	0.540	0.803	0.819
	CP2	0.576	0.799	
	CP3	0.401	0.811	
	CP4	0.354	0.813	
	CP5	0.558	0.800	
	CP6	0.449	0.807	
	CP7	0.576	0.799	
	CP8	0.424	0.809	
	CP9	0.558	0.800	
	CP10	0.445	0.809	
	CP11	0.443	0.829	
	CP12	0.505	0.803	
	CP13	0.391	0.817	
	CP14	0.625	0.798	
	CP15	0.576	0.799	
	CP16	0.371	0.819	
Scientific Research Outcome Performance	OP1	0.400	0.579	0.734
	OP2	0.526	0.628	
	OP3	0.470	0.653	
	OP4	0.390	0.593	
	OP5	0.404	0.740	
	OP6	0.361	0.742	
Scientific Research Work Performance	JP1	0.693	0.909	0.917
	JP2	0.749	0.906	
	JP3	0.762	0.905	
	JP4	0.621	0.913	
	JP5	0.752	0.906	
	JP6	0.547	0.917	
	JP7	0.799	0.902	
	JP8	0.745	0.906	
	JP9	0.560	0.918	
	JP10	0.799	0.902	

As we can see from the table, the numbers of overall Cronbach's Alpha of creative personality, scientific research outcome performance and scientific research work performance are greater than 0.7, and the numbers of Corrected Item-Total

Correlation of each measurement item is greater than 0.35. Therefore, the 3 variables and 32 measurement items have relatively good reliability.

We used KMO and Bartlett's test to ensure the data is suitable for Factor Analysis.

The results of testing creative personality are in Table 6.

Table 6 Creative Personality Validity Testing Results

KMO		.713
Bartlett's Test of Sphericity	Approx. Chi-Square	315.881
	df	120
	Sig.	000

As we can see from the table, KMO is between 0.7 and 0.8. Sig. of Bartlett's test is less than 0.01. It means these 16 measurement items have significant correlation with each other, and they are suitable for Factor Analysis.

The results of testing scientific research outcome performance are in Table 7.

Table 7 Scientific Research Outcome Performance Validity Testing Results

KMO		.725
Bartlett's Test of Sphericity	Approx. Chi-Square	158.278
	df	15
	Sig.	.000

As we can see from the table, KMO is between 0.7 and 0.8. Sig. of Bartlett's test is less than 0.01. It means these 6 measurement items have significant correlation with each other, and they are suitable for Factor Analysis.

The results of testing scientific research work performance are in Table 8.

Table 8 Scientific Research Work Performance Validity Testing Results

KMO		.866
Bartlett's Test of Sphericity	Approx. Chi-Square	391.297
	df	45
	Sig.	.000

As we can see from the table, KMO is between 0.8 and 0.9. Sig. of Bartlett's test is less than 0.01. It means these 3 measurement items have significant correlation with each other, and they are suitable for Factor Analysis.

Now we proceed to test the 5 hypotheses.

H1: There are significant differences in scientific research outcome performance between students with and without arts instruction.

Independent sample test results in scientific research outcome performance of students with and without arts instruction are in table 9.

Table 9 Independent Sample Tests Results in Scientific Research Outcome Performance of Experimental Group and Control Group

Mann-Whitney U	3760.500
Wilcoxon W	14345.500
Z	-1.380
Asymptotic Significance (2-sided)	.167

As we can see in Table 9, the asymptotic Significance (2-sided) between two groups is greater than 0.05. It means there is no significant difference in scientific research outcome performance between students with and without arts instruction. H1 is not supported.

H2: There are significant differences in scientific research work performance between students with and without arts instruction.

Independent sample test results in scientific research work performance of students with and without arts instruction are in table 10.

Table 10 Independent Sample Tests Results in Scientific Research Work Performance of Experimental Group and Control Group

Mann-Whitney U	4003.500
Wilcoxon W	5773.500
Z	-.718
Asymptotic Significance (2-sided)	.473

As we can see in Table 10, the asymptotic Significance (2-sided) between two groups is greater than 0.05. It means there is no significant difference in scientific research work performance between students with and without arts instruction. H2 is not supported.

H3: There are significant differences in creative personality between students with and without arts instruction.

Independent sample test results in creative personality of students with and without arts instruction are in table 11.

Table 11 Independent Sample Tests Results in Creative Personality of Experimental Group and Control Group

Mann-Whitney U	3116.500
Wilcoxon W	13701.500
Z	-3.041
Asymptotic Significance (2-sided)	.002

As we can see in Table 11, the asymptotic Significance (2-sided) between two groups is less than 0.01. It means there is significant difference in creative personality between students with and without arts instruction. H3 is supported.

H4: Creative personality has a significant effect on science and engineering students' scientific research outcome performance.

The one-way ANOVA results of the effect creative personality has on scientific research outcome performance in the experimental group are in Table 12.

Table 12 One-Way ANOVA Results of the Effect Creative Personality Has on Scientific Research Outcome Performance

	SS	Df	MSS	F	Sig.
Between	1718.871	18	95.493	2.176	.020
Within	1755.264	40	43.882		
Total	3474.136	58			

As we can see in Table 12, Sig.<0.05. It means creative personality has a significant effect on science and engineering students' scientific research outcome performance. H4 is supported.

H5: Creative personality has a significant effect on science and engineering students' scientific research work performance.

The one-way ANOVA results of the effect creative personality has on scientific research work performance in the experimental group are in Table 13.

Table 13 One-Way ANOVA Results of the Effect Creative Personality Has on Scientific Research Work Performance

	SS	Df	MSS	F	Sig.
Between	1375.499	18	76.417	2.272	.015
Within	1345.179	40	33.629		
Total	2720.678	58			

As we can see in Table 13, Sig.<0.05. It means creative personality has a significant effect on science and engineering students' scientific research work performance. H5 is supported.

This paper has conducted empirical analysis on the relationship between the variables through Nonparametric tests - Two independent sample tests and one-way ANOVA of SPSS 20.0. Table 14 is the testing results of research hypotheses.

Table 14 Testing Results of the Research Hypotheses

Hypothesis Content	Testing Result
H1: There are significant differences in scientific research outcome performance between students with and without arts instruction.	Not Supported
H2: There are significant differences in scientific research work performance between students with and without arts instruction.	Not Supported
H3: There are significant differences in creative personality between students with and without arts instruction.	Supported
H4: Creative personality has a significant effect on science and engineering students' scientific research outcome performance.	Supported
H5: Creative personality has a significant effect on science and engineering students' scientific research work performance.	Supported

CONCLUSIONS

Here are the conclusions based on the research analysis above.

Conclusion 1: Arts instruction doesn't have significant effect on scientific research performance.

Conclusion 2: Arts instruction can affect creative personality, and then affect scientific performance. Creative personality plays an intermediary role between arts instruction and scientific research performance.

We conducted the experiment to explore the causal relationship between the variables. After conducting empirical analysis on valid samples, we found that there is no direct significant effect between arts instruction and scientific research performance. However, arts instruction has significant effect on creative personality, and creative personality has significant effect on science and engineering students' scientific research performance. Therefore, through mediator creative personality, arts instruction can indirectly affect science and engineering students' scientific research performance. The process can be depicted in the figure below.

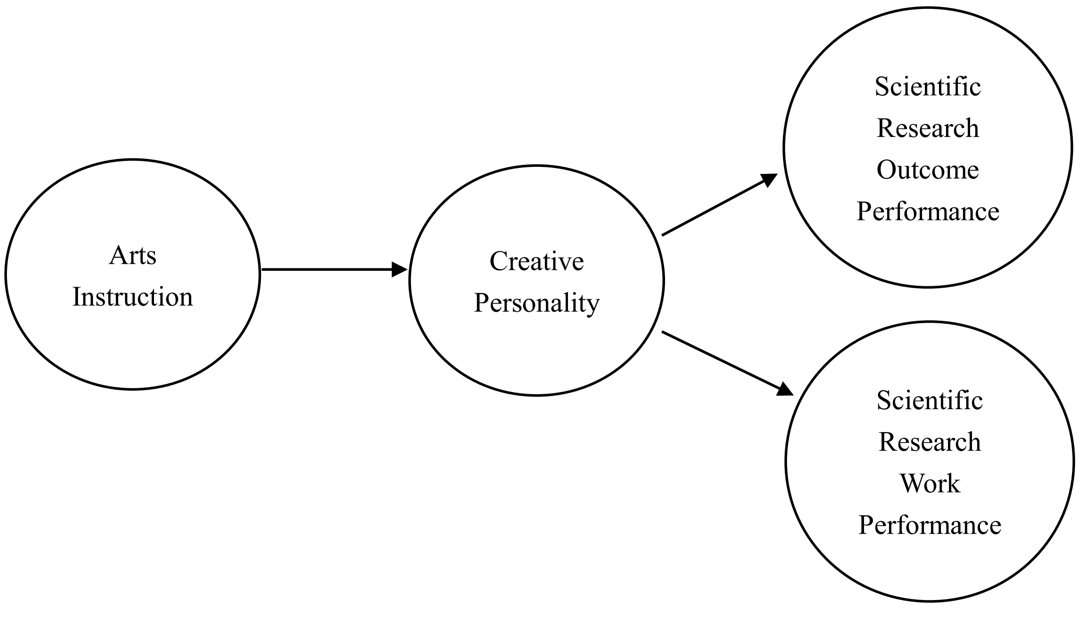

Figure 2 Mechanism of Arts Instruction Affecting Scientific Research Performance

It is reasonable to conclude that, simply doing arts would not automatically bring about better performance in other subjects [16]. However, previous research does show that arts education increases students' interest, motivation, self-esteem and willingness to try new things [17], which are closely related to creative personality.

It is increasingly expected that universities could foster more creative engineering students [18]. However, "evocation of 'more creativity' has been limited to rhetorical flourishes in policy documents" [19]. Educational programs focus excessively on deep technical specifications, with little room in the curriculum for creativity [20]. Some universities have realized this situation and start to pay more and more attention to creativity instruction. Many ways such as brainstorm become more and more popular in engineering curricula. Among the multiple ways used to cultivate creativity, arts integration might be one of the most underappreciated ways.

Based on the conclusions of this paper, we suggest that we should attach importance to arts education. Some reports at both the K-12 [21] and professional levels [22] have shown that integrating arts and science/engineering could have unexpected effects. Some colleges such as Rose-Hulman Institute of Technology have even stepped further to explore a new combination of arts and engineering, in which the course was provided from an art perspective with examples of engineering pulled in to reinforce topics in art, rather than creating an engineering course with examples of art pulled in. This course engaged students in the arts better and increased students' creativity [23]. We suggest that more colleges should conduct this kind of exploration and it can probably improve students' scientific research performance or even help them become better scientists. After all, studies show that Nobel laureates are more artistically engaged than the "average" scientist [24].

There are some limitations of this research. Firstly, the sample size is relatively small due to the limit of time and cost. Secondly, we didn't take the training details (e.g., duration, mode, content) of arts instruction into consideration, which may help us to interpret the model better. Thirdly, other variables such as gender and subject, which might affect scientific research performance, were not taken into consideration.

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