The Art of SCIENCE Learning

The Impact of Arts-Based Innovation Training on the Creative Thinking Skills, Collaborative Behaviors and Innovation Outcomes of Adolescents and Adults

A Research Study Report
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Executive Summary

PROJECT BACKGROUND: The Art of Science Learning Project (AoSL) is a National Science Foundation (NSF)-funded initiative, founded and directed by Harvey Seifter, that uses the arts to spark creativity in science education and the development of an innovative 21st Century STEM (Science, Technology, Engineering and Math) workforce. In 2007, Seifter, along with artist/scientist Todd Siler and choreographer Liz Lerman, led an NSF symposium on the relationship between the arts, STEM learning and workforce development. In 2008, Seifter and colleagues at New York's Learning Worlds Institute held a series of roundtables with science educators, which revealed a broadly shared belief in the connection between the investigative nature of science and the arts, and an appreciation for the potential of arts-based learning to foster passion for exploration and discovery in young learners. These meetings played an important role in designing a proposal, which was subsequently funded by the National Science Foundation (DRL-0943769). In 2011, Phase 1 of the project convened 425 science educators, teaching artists, museum professionals, classroom teachers, business leaders, policymakers, and academic researchers in regional conferences at the Smithsonian Institution, Illinois Institute of Technology and California Institute of Telecommunications and Information Technology (Calit2). The goals were to explore the connection between the arts, innovation and economic competitiveness; create communities of practice by sharing educational resources, curricula, and best practices that use ABL to strengthen STEM learning; and experience first-hand arts-based educational techniques that develop critical and collaborative thinkers for the STEM workforce.

At the writing of this report the Art of Science Learning project is in Phase 2, funded by the NSF (DRL-1224111) to develop a new arts-based STEM innovation curriculum for adolescent and adult learners; three year-long arts-based incubators for innovation in STEM learning and practice to test and refine the curriculum; a traveling art/science exhibition; and public programs that use the project's activities and outcomes to advance civic engagement with STEM. Phase 2 also included research comparing the impact of arts-infused STEM innovation training with traditional project-based STEM innovation training, a multi-year research project that was independently carried out by Audience Viewpoints Consulting. This report contains the results of this Phase 2 research.

RESEARCH DESIGN: AoSL's research component was designed to test the idea that integrating the arts into STEM-related innovation training would result in enhanced creative thinking skills, more extensive collaboration, more robust innovation processes and improved innovation outcomes. Two cities, Worcester, Massachusetts and San Diego, California, served as the sites for the research study. High school students were the sample population in Massachusetts, and early career STEM professionals in California. At both sites the AoSL project team hosted five week-long innovation training sessions, with each group meeting for a half day per week, totaling roughly 20 hours of involvement for each participant in the research project. The training sessions involved project-based learning focused on the front end of innovation, with projects addressing local STEM challenges (transportation alternatives in Worcester, water resources in San Diego). Over the course of the five weeks, teams of participants created simple prototypes and business cases for new products, processes and services intended to address these challenges. The training curriculum, grounded in best practices derived from the Product Development Management Association Body of Knowledge, included the key concepts of innovation, STEM content specific to each local challenge, and collaborative project innovation activities and exercises.

There were three main hypotheses that guided this research:

1. **Arts-based innovation training, compared to traditional innovation training, improves an individual's creative thinking skills including critical thinking, divergent thinking, problem identification, convergent thinking and problem solving.**
2. **Arts-based innovation training, compared to traditional innovation training, increases individual collaborative behaviors within a team context.**
3. **Arts-based innovation training, compared to traditional innovation training, enhances the novelty, impact and feasibility of team innovation outcomes.**

In order to test these hypotheses, the research study used a quasi-experimental design with a pre-test, post-test intact group design, including a control group for comparison purposes. Intact group design means that the same participants filled out the pre-test and post-test, in order to compare how responses changed from the beginning to the end of their participation. Individuals who participated in the study were given a pre-recruitment survey and based on this were assigned to either the control or treatment group, and counter-balanced based on related variables such as interest and experience with the arts and sciences. Individuals were distributed as evenly as possible between the control and treatment groups based on demographic and psychographic variables collected during the pre-test.

METHODS: Art of Science Learning Incubators at EcoTarium (Worcester) and Balboa Park Cultural Partnership (San Diego) served as host sites for the research studies, with Art of Science Learning staff embedded in both institutions providing local administrative support. A very similar recruitment approach was used in both cohorts (Worcester and San Diego) where the local team members sent an invitation on behalf of the researcher project. High school students were recruited for the Worcester cohort, and early career STEM professionals were recruited for the San Diego cohort. Both groups were recruited based on a number of criteria (age, experience with STEM, experience with the arts, etc.). A total of 16 groups participated in the study: 8 student groups (4 control, 4 treatment) in Worcester, and 8 early career STEM professional adult groups (4 control, 4 treatment) in San Diego. Each group included 7 to 10 individuals. Both control and treatment trainings were held at separate times, and while participants knew that there was another similar group meeting the same day, they were unaware that the training varied. Control and treatment groups both used hands-on project-based learning and an approach to innovation grounded in Best Practices from the Product Development Management Association, as articulated in the PDMA 2014 Body of Knowledge (Kahn, 2013). The treatment curriculum replaced 9 hours of the traditional innovation pedagogy used in the control curriculum with 9 hours of arts-based activities designed to achieve the same learning objectives. In this manner only the approach was varied, to provide for the cleanest comparison of the two approaches.

There were seven methods used, in order to triangulate the research findings: 1) a recruitment survey from those interested to determine eligibility for participation, 2) pre-workshop survey, 3) post-workshop survey, 4) creative thinking skills assessments, 5) observations of groups during weekly meetings, 6) a follow-up transferability of skills learned survey with a subset of participants, and 7) scoring of the team's innovation products, processes and services by an expert panel of judges. Methods 1 and 2 were conducted before the training began; method 3 was conducted in the weeks following the training; 4 and 5 included data collected during the 5-week training period; and methods 6 and 7 were conducted several months following the training.

MAIN FINDINGS (based on the hypotheses):

Hypothesis 1: Arts-based innovation training, compared to traditional innovation training, improves an individual's creative thinking skills including critical thinking, divergent thinking, problem identification, convergent thinking and problem solving.

Mapping Changes in Creative Thinking

As creativity is a complex construct, there were multiple measurements of different attributes of creativity within the research, including validated scales from other studies as well as instruments and items created for this project. Scales from other studies asked participants to rate their personal capacities towards a variety of creative processes, and their preferences for creativity at a variety of stages of development. These included the ECCI scale (Epstein, Schmidt, & Warfel, 2008), two critical thinking scales and the Creative Problem Solving Profile (CPSP) developed by Basadur, Graen, and Wakabayashi (1990), which measures individual strength within four different components of the creativity process: generation, conceptualization, optimization, and implementation. A creativity skills instrument created for this project asked participants to identify problems related to a given Innovation Challenge, select one to work on, generate possible solutions to the selected problem, select one solution, and explain their choices (see Appendices F through H for the full exercises). The same exercise was given twice: once in the opening 15 minutes of the initial session, and again during the closing 15 minutes of the final session five weeks later. A different Innovation Challenge was used for the second use of the exercise to prevent any practice effects. A project-developed participant transferability of skills survey measured the extent to which engaging in the five-week research challenge had residual impact four months later. The research team was interested in whether participants were able to apply what they did during the training to their own subsequent experiences, including school, extracurricular activities and home or personal lives, and to what extent participants expected that impact to continue or grow in the future.

High School Students

Overall, creative competencies, as measured by the ECCI scale, significantly increased in the high school treatment group, and decreased (though not significantly) within the control group. There were no significant differences between treatment and control group change scores for high school students on the CPSP scale. Some of the most striking findings were within the metrics from the outcomes of the creativity skills test – 7 of the 16 creative skills measures showed a statistically significant increase from the pre-test to the post-test for the treatment group. These differences were within both convergent and divergent skills, with stronger evidence for an increase in divergent thinking skills. For the measures specifically about critical thinking, statistically significant differences were found between the control and treatment groups for both of the main critical thinking scales used, with the treatment group scoring as much as three-quarters of a point higher. In this case, there were no differences between pre- and post-test measures for the treatment group. The students who were in the control group scored significantly lower on the post-test compared to the pre-test. The combination of lack of change in the treatment group and a decrease in scores within the control group resulted in statistically significant differences between the groups, but no evidence of gain within either of the high school groups. Significant differences also emerged around skill transferability. High school students in the treatment group were more likely to report a positive impact and anticipate future impact from these experiences (compared to the control group), with some of the differences being quite large.

Early Career STEM Professionals

There was a statistically significant decrease in creativity in both treatment and control groups in early career STEM professionals on the ECCI scale. There were no significant differences between treatment and control group change scores for early career STEM professionals on the CPSP scale. Both the early career STEM professionals treatment and the control groups showed some increases in creative skills from pretest to post test, including within measures of convergent and divergent thinking. The two groups showed gains within different skills. When compared against one another, one statistically significant difference between the treatment and control groups emerged, in the ability to identify and clearly frame problems arising from a given challenge. No differences were found between the early career STEM professionals groups in the critical thinking scale. The treatment and the control groups both had slight increases from the pre to post tests, and no differences were found between the two groups. The range of scores was large, meaning that both the arts-based and the traditional innovation training had differentiating effects on critical thinking for adults, in that some benefited greatly but others lost ground. There is likely some other variable or set of variables that determines how the training will impact critical thinking skills; however, analysis of the variables to date has not uncovered specific leads on what those influences might be. No significant differences between control and treatment were found around skill transferability.

Hypothesis 2: Arts-based innovation training, compared to traditional innovation training, increases individual collaborative behaviors within a team context.

Assessing Individual Collaborative Behavior

Researchers observed the behaviors of individuals within their groups during substantial parts of each of the sessions they were working together over the five-week period, tracking changes in the prevalence of specific behaviors of individuals in each group over time. In an attempt to triangulate a realistic depiction of an individual's collaboration and participation in the Innovation Challenge, at the end of each workshop session participants were also asked to rate themselves, and each individual on their teams, on a series of behaviors that aligned with the behaviors recorded by data collectors in the workshop observation sheet.

High School Students

Based on observational data, comparisons were made on each behavior over the five-week period for both the control and treatment groups. In looking at each group individually, both treatment and control groups showed similar, and statistically significant, increases in trust in moving towards a solution, being transparent in communication, the ability to disagree productively, creating a culture of mutual responsibility and productively managing disruption. Control groups showed statistically significant increases over the five-week period in sharing leadership, being transparent in communication, defining a common purpose, and creating a culture of mutual accountability. Treatment groups showed statistically significant increases over the five-week period in emotionally intelligent behavior, empathic listening, and the ability to disagree productively.

When comparing the two groups directly, there were 8 of the 11 behaviors where the frequency and patterns of the behaviors differed significantly between control and treatment. In 6 of these 8 behaviors, the treatment group showed the stronger performance: shares leadership, trust in moving toward a solution, transparent in communication, emotionally intelligent behavior, disagree productively and defining a common purpose. In the remaining 2 of these 8 behaviors (creating a culture of mutual accountability and productively manages disruption) the control group showed marginally,

but statistically significant, stronger performance.

An additional analysis allowed for a comparison between the control and treatment groups during their final (R5) sessions when participants were completing their course of study and teams were finishing their work on the challenge and making all of their final decisions with respect to business cases (see Appendix J) and presentations. Thus, R5 data gave a sense of the cumulative impact of the full twenty-hour intervention on collaborative behavior of control and treatment groups. When comparing the two groups directly, statistically significant differences were seen with respect to the frequency of five behaviors during this session: shares leadership, emotionally intelligent behaviors, mutual respect, ability to disagree productively, and defining a common purpose. All of these showed a higher level of occurrence for the treatment group.

Self-reported team collaboration ratings were markedly different; only two items (mutual respect and trust) showed a significant change from pre-test to post-test, and it was the control group, rather than the treatment group, that showed a significant increase in both cases. Treatment groups showed statistically significant greater increases in sharing leadership, emotionally intelligent behavior and defining a common purpose, compared with the control groups.

Early Career STEM Professionals

The observational data reveal significant pre/post increases in seven collaborative behaviors among the treatment groups: sharing leadership, active following, emotionally intelligent behavior, empathic listening, mutual respect, trust in moving towards a solution, and transparency in communication. Only one of these behaviors (emotionally intelligent behavior) also saw an increase among the control group over the five weeks.

When comparing the two groups directly, there were 7 of the 11 behaviors where the frequency and patterns of the behaviors differed significantly between control and treatment. In 4 of these 7 behaviors, the treatment group showed the unambiguously stronger performance. These behaviors were active follower, mutual respect, trust in moving toward a solution, and transparent in communication. In 2 of the behaviors, sharing leadership and empathic listening, the control group showed a marginally, but statistically significant, stronger performance. In emotionally intelligent behavior, the treatment group showed a marginally, but statistically significant, stronger performance.

In comparing just the last session, there were statistically significant behavioral differences for 2 of the 11 observed behaviors were observed: mutual respect and trust in moving towards a solution. For both of these, the treatment group had a significantly higher occurrence of these behaviors.

Once again, there were striking differences between observational data and self-report; there were no statistically significant differences for the self-reported team collaboration measures for the early career STEM professionals.

Hypothesis 3: Arts-based innovation training, compared to traditional innovation training, enhances the novelty, impact and feasibility of team innovation outcomes

Judging Innovation Outcomes

A panel of three national experts, drawn from the selection committee of the Product Development Management Association (PDMA)'s Outstanding Corporate Innovator Awards, developed an assessment

rubric identifying and weighting seven measures to gauge the quality of the innovation outputs, and subsequently applied the rubric to the new product, process and service concepts developed by the teams. Panelists assembled at the University of Indiana's Kelly School of Business to review business cases created by the teams (working on a template developed by Harvey Seifter), PowerPoint presentations created by each team about its innovation, pre-recorded videos of each team's concept presentation, and pre-recorded videos of each team's responses to a standardized set of questions. Scoring was done without panelists knowing which of the 16 groups were control or treatment groups.

High School Students
Treatment outperformed control on all seven individual items scored. Four of these differences were statistically significant: insight into challenge, clarity and relevance of the problem, problem solving strategy, and the potential impact of their proposal. While the differences between control and treatment on the other three items scored did not reach statistical significance, the treatment group did have higher ratings than the control group on each. Similarly, in the total weighted team innovation outcome score, which used an average weighted total score across all items for the control group compared to the average weighted total score across all items for the treatment group, the treatment group had higher ratings but the difference did not reach statistical significance.

Early Career STEM Professionals
None of the differences between control and treatment on the seven individual items scored were statistically significant for the early career STEM professionals. Similarly, there was no statistically significant difference between the control and treatment groups in the total weighted score across all items.

Hypothesis 3 Summary
It was a very important result that the expert panelists rated the high school products, processes and services of the treatment teams significantly higher that those of the control teams in terms of insight, clarity, problem solving strategy and potential impact. It is possible that this lack of findings from the adult teams may result from using a curriculum that was developed specifically for adolescents. Further study to determine whether adult findings would change with the substitution of a curriculum specifically designed for use with adults would be very useful.

RESEARCH CONCLUSIONS: The study looked to identify differences in creativity and collaboration when using an arts-based approach to grappling with local issues and challenges. As noted in the findings, there were a number of positive findings from the study:

- High school treatment groups showed a large number of statistically significant positive differences in creative thinking skills from pretest to post test. For the control groups, there were no gains on any variable after the training. [Hypothesis 1]

- High school treatment groups showed statistically significant gains in four of five divergent thinking skills from pretest to post test. For the control groups, there were no such gains. [Hypothesis 1a]

- High school treatment groups showed statistically significant gains in three of six convergent thinking skills from pretest to post test. For the control groups, there were no such gains. [Hypothesis 1b]

- High school treatment groups showed a statistically significant positive gain in critical thinking skills from pretest to post test. The control groups showed no such gain. [Hypothesis 1c]

- High school treatment groups showed significantly stronger performance than control groups in sharing leadership, trust in moving toward a solution, transparency in communication, emotionally intelligent behavior, productive disagreement, and defining a common purpose, based on observational data. [Hypothesis 2]

- High school students perceived their own collaborative behaviors having positive increases over the training for all of the measures. [Hypothesis 2]

- Adult early career STEM professional groups showed significantly stronger performance than control groups in emotionally intelligent behavior, mutual respect, active following, trust in moving toward a solution and transparency in communication, based on observational data. [Hypothesis 2]

- Early STEM career professionals perceived their own collaborative behaviors as having positive increases over the training for almost all of the measures. [Hypothesis 2]

- High school treatment groups developed significantly stronger final innovation outputs than the control groups. External judges found large and significant positive differences between control and treatment groups in insights into the challenge, analytic clarity, problem solving strategy and potential impact. [Hypothesis 3]

- High school student treatment groups reported a significantly greater incidence of applying their innovation learning experiences to work, school, volunteer and extracurricular activities than the high school student control groups.