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
Prepared by:

Kate Haley Goldman
Steven Yalowitz, Ph.D.
Erin Wilcox, M.A.

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Harvey Seifter, Principal Investigator

Audience Viewpoints Consulting

13148 Rounding Run Circle, Herndon, VA 20171 t: 831-224-3085 www.audienceviewpoints.com

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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.

Discussion and Implications for Future Research

There was a trend of a stronger overall impact of the training on students rather than adults (especially in the creative and collaborative thinking self-report measures), with the notable exception of observed collaborative behavior. There are several possible explanations for this trend. It may be that an arts-based approach to innovation training is more effective for people who are still in school, compared to those who have already started their STEM careers. It is also possible that the different ages and consequent experiences of the participants had something to do with the difference in results. A third possible explanation lies in the decision made by the researchers to use the curriculum designed for the high school students with the adult participants as well, rather than modifying the adult curriculum to reflect differences between the two populations. This decision was important to the researchers since having very similar, if not identical, approaches was necessary in order to make more direct comparisons between the two cohorts, as well as combine them as appropriate to the analyses. If the curricula had been different then it would have been impossible to know whether any variation in the results were due to the different audiences or the different pedagogical approaches being used. It will be important to test, in future studies, whether or not using an arts-based innovation training curriculum specifically designed for adult learners would lead to a stronger impact on those learners.

It is worth noting that there were a number of positive results from the treatment approach for the early career STEM professionals with respect to the observed collaborative behaviors, while the stronger impact with students happened with individual creative thinking skills and team innovation outcomes. It may be that the arts-based approach yielded positive differences in how the adults approached group interactions, without translating into a change in the individuals themselves or the solutions they came up with. It would be interesting to see if an approach to the adult curriculum that allows more scope for collaborative activity than was included in the high school curriculum, may prove effective in yielding positive changes to individual creative thinking skills or team innovation outcomes. It is also possible that the lack of difference among the adults in much of the validated self-reported measures (CPSP, Creative Processes) could be a result of the scales being more useful in other situations and thus not as valid for this type of approach. Meanwhile, the observational measures and related weekly self-reported team collaboration measures yielded impacts between control and treatment conditions. Given that these items were specifically created for this study, it would be expected that they would yield some significant differences. While these instruments were carefully planned and created, they did not go through validity and reliability testing, so further validation of the instruments would be useful to see whether these observational measures would be helpful in other studies related to creativity, collaboration, and arts-based approaches in STEM. One interesting difference is that in many cases, observations, activity tests and team outcomes showed differences, while previously validated self-perceived measures did not show the same differences.

As noted in the report and findings above, there were times where the treatment or control groups (and in some cases, both the treatment and control groups) showed a decrease in outcome measures, including for both creativity and collaboration. The researchers do not have a single explanation for this; rather, there are some different possibilities. It could be that there is something inherent in the measures that impacted the findings in this particular study, (i.e., the structured learning of innovation processes that formed the core of both the control and treatment curricula, or the particular arts-based approach used in the treatment curriculum). There could also be some unmeasured differences unevenly distributed between the control and treatment groups that contributed to these differences, although at this point there is not any specific evidence towards what they might be. Variability was strong in terms of impact, with high standard deviations at some points. This suggests there was an underlying variable not measured in pre-art, pre-science or creativity scores that might help determine whether the training would have impact. Future research could delve into this area. Additionally, there may be something about the tasks themselves that account for the differences. Without specific evidence or an indication for which factors may have influenced this decrease in the treatment group, it is difficult to speculate about why this may be the case. Further research could duplicate the study to see whether or not similar results for the treatment group are found, allowing for a better understanding of this phenomenon.

In looking at potential real world applications of this research to the learning and practice of STEM innovation, it seems that different approaches to the integration of arts-based learning may work best for different audiences. For high school students, the arts-based approach was clearly more effective in fostering creative thinking and problem solving, suggesting that it may be more effective than a traditional approach for students. This has potentially far reaching implications for how adolescents might best experience STEM and innovation learning in a wide range of formal and informal settings. Further research could investigate which specific factors would be more likely to lead to positive outcomes, and potential strategies for optimizing the impacts of arts-based learning.

For adults, outcomes suggest that an arts-based approach may be most effective when used to increase collaboration or strengthen teams and collaborative culture in a professional setting. It would also be valuable to explore the possibility that building increased opportunities for collaborative exploration into an adult arts-based curriculum may yield greater impact on individual creative thinking skills and team innovation outcomes. It is possible that the conditions that need to be present to positively impact adult creative thinking skills and innovation outcomes may be different from those needed for students. There may also have been some different kinds of creative thinking skills that could be enhanced with an arts-based approach. These are important questions for further investigation.

In both the adolescent and early career STEM professional cases, larger studies with more than one treatment group for each audience would be invaluable; this seems an obvious next step in building on this research.

Given the dearth of research in this area, and the uniqueness of the arts-based approach to the learning and practice of STEM innovation, it is not surprising that even with the compelling and promising findings in this study there are a decent number of unanswered questions. While a quasi-experimental approach was able to be used for the current study, an experimental study would go even farther in answering some of the more fundamental questions still remaining around creativity and collaboration, many of which have been touched on above.

Based on the outcomes of this study, we strongly recommend future research into the following questions as particularly useful to the advancement of knowledge in this field:

- **Does arts-based learning foster engagement in adolescent and adult learners?** For both cohorts, the attrition rate was considerably higher for the control group than for the treatment group. While data were not collected during this study about why participants were no longer continuing with the program, one possible explanation is that the arts-based approach engendered a greater level of engagement than the traditional approach. This would be interesting to pursue in further studies.

- **How can arts-based learning be most effectively integrated into innovation training?** We observed many powerful positive impacts of this type of innovation training, when compared with a more traditional pedagogical approach.
    - Are there particular arts-based activities and applications that drove the impacts on creative thinking skills, collaborative behaviors and innovation outcomes that we observed and measured? Might the use of other such activities further strengthen or broaden those impacts?
    - Which types and what amounts of arts-based learning, and in what sequence, would optimize impact?

- **Can arts-based learning serve to neutralize the potential negative impacts of traditional high school innovation training on creativity?** The high school student treatment group had 7 creative thinking skill variables that showed a significant increase from pre to post, and none of these were significantly different for the control group. Likewise, the high school student control group had 5 creative thinking skill variables that showed a significant decrease from pre to post, yet there was no significant decrease for the treatment group. These results strongly suggest that arts-based learning may have the capacity to overcome and neutralize what appears to be the negative impact of traditional innovation training on adolescent creative thinking. Both the question of whether traditional innovation training depresses creativity in adult learners, and the potential of arts-based learning to overcome any negative impact, bears further investigation.

- **Does the use of arts-based learning enhance the cognitive gains of adolescent or adult learners?** This study did not examine the extent to which the arts-based approach to innovation training increases knowledge and understanding of STEM content, both with respect to learning in general and for specific topics. Several of our findings, however, suggest that this may be a possibility. This is an important topic to pursue in future studies.

- **Does arts-based learning foster greater post-learning impact, agency and optimism in adolescent learners?** In a survey four months after the intervention, the high school student treatment group reported a significantly greater incidence of applying their innovation learning experiences to work, school, volunteer and extracurricular activities than the high school student control group. The treatment group also showed a much greater optimism that they would be likely to apply their innovation learning experiences to future work, school, volunteer and extracurricular activities than the high school control group. These findings suggest the value of investigating the impact of arts-based learning on adolescent agency and optimism.

- **Is self-report an accurate way to assess collaboration in groups?** Although neither control nor treatment groups rated themselves as having improved on any of the self-reported team rating measures, observers recorded the treatment groups as having engaged in many of these behaviors significantly more by the last session. These findings suggest the importance of including direct observation in assessments of the nature and extent of group collaboration, rather than simply relying on self-report from participants.

Introduction and Project Background

The Art of Science Learning Phase 2 is a four-year National Science Foundation-funded initiative (Grant #1224111) that uses the arts to spark creativity in science education and the development of an innovative 21st Century STEM workforce. The initiative is built on Art of Science Learning's Phase 1, as well as decades of work by Project Director Harvey Seifter and colleagues, exploring the impact of artistic skills, processes and experiences on creativity, innovation and learning (an educational methodology known as "arts-based learning"). The goal of the project's Phase 2 development activities was to experiment with arts-based learning in a variety of "innovation incubator" models in cities around the country. Modeled on business "incubators" or "accelerators" that are designed to foster and accelerate innovation and creativity, these STEM incubators generate collaborations of different professionals and the public around STEM education and other STEM-related topics of local interest that can be explored with the help of creative learning methodologies. These include innovative methods to generate creative ideas, ideas for transforming one STEM idea to others, drawing on visual and graphical ideas, improvisation, narrative writing, and the process of using innovative visual displays of information for creating visual roadmaps.

The Art of Science Learning, in collaboration with Balboa Park Cultural Partnership, Phase 2's national administrative sponsor, and several informal science education and other cultural and business organizations in San Diego, Chicago (notably the Museum of Science and Industry), and Worcester, MA (principally EcoTarium and Clark University) implemented a research and development project to investigate a range of possible approaches for stimulating the development of 21st Century creativity skills and innovative processes at the interface between informal STEM learning and methods for creative thinking. The project goals included developing new ways to use arts-based learning to enhance STEM innovation skills among a range of learners, developing impactful new models using arts-based learning to strengthen informal STEM learning and advance understanding of the potential impacts of arts-based learning on the public's understanding of and engagement with STEM. A particular focus was on strengthening the 21st Century workforce skills of high school students and early career STEM professionals, and creating deliverables and resources for the field to foster the integration of the arts and STEM fields. Activities have included the following: the formation and collaborative processes of two incubator sites, an independent research study (this report), the development of a comprehensive arts-based innovation process curriculum for STEM learners, professional development based on the curriculum, public engagement events and exhibits, a project website and tools for social networking, and project evaluation. A national advisory council included professionals in education, science, creativity, and business.

For more information about the project see the following:

- Art of Science learning website: http://www.artofsciencelearning.org/
- NSF's website about the project at http://www.nsf.gov/awardsearch/showAward?AWD_ID=1224111&HistoricalAwards=false
- The project site on the informalscience.org site at http://informalscience.org/projects/ic-000-000-000-099/Integrating_Informal_STEM_and_Arts-Based_Learning_to_Foster_Innovation

As mentioned above, the project included a summative evaluation of the incubators by Slover-Linnett (a professional evaluation firm) that focused on the goals and objectives of the project. The current report summarizes the separate research effort conducted by Audience Viewpoints Consulting (AVC) that looked into better understanding the theory behind the intersection of arts and sciences in collaborative processes focused on solving real-world problems. AVC was contracted to conduct independent research studies at sites in Worcester, Massachusetts (at the EcoTarium) and San Diego, California (at the Balboa Park Cultural Partnership). The main goal of the research was to better understand the affordances of using a curriculum that integrated the arts into STEM innovation, including the use of arts-based processes and practices in trying to solve specific problems or ‘challenges’ identified in the community.

The research focused on both high school students and early career STEM professionals in order to better understand the conditions and factors related to specific outcomes. High school students were included in the research since they are a population that is learning about and becoming more interested in STEM, and these are formative years for thinking about and engaging in these topics. The early career STEM professionals were included in order to gather information about the potential for an arts-based approach to be used with those just beginning or continuing to engage in STEM-based fields. Including both would allow for a better understanding of the potential of engaging an arts-based approach to collaborative problem solving in different audiences.

Study 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 in the 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 to address these challenges. The training curriculum, grounded in best practices derived from the Product Development Management Association Body of Knowledge, included key concepts of innovation, STEM content specific to each local challenge and collaborative project innovation activities and exercises. The decision was made to use the curriculum designed for use with adolescents for both groups, in order to allow for a comparison between the high school students and early career STEM professionals, as well as combine them as appropriate to the analyses. Without using the same curriculum, it would have been impossible to determine whether any positive results were generalizable across different audiences.

Below is the basic schedule for each workshop day, comparing activities and discussion between the control group and the treatment group (see **Table 1**). The workshop staff utilized the same curriculum and maintained the same schedule for the Worcester cohort and the San Diego cohort in order to compare differences between the groups of adults and students.

The study used a quasi-experimental design with pre-test, post-test intact group design, in order to allow control for other variables (see **Figure 1** below for the design and methods for the control and treatment groups). The control groups were included to provide a comparison to treatment group participants, who experienced the arts-based activities. Both groups experienced a STEM innovation workshop; however, the treatment group also experienced the arts-based activities, which allowed for isolating and understanding the added value of the arts-based activities to the workshop experience. The study also incorporated mixed methods; while the focus was on quantitative data, critical qualitative data were captured to better understand the individual experience of participating in the Innovation Challenges.

There were three main hypotheses, which included sub-hypotheses:

1. Arts based learning influences individuals' creative thinking skills.
    a. Arts-based innovation training increases an individual's ability to employ convergent thinking compared to traditional innovation training.
    b. Arts-based innovation training increases an individual's ability to employ divergent thinking compared to traditional innovation training.
    c. Individuals who participate in arts-based innovation training have a greater increase in critical thinking skills than those who participate in traditional innovation training.

2. Arts based learning influences innovation-related process behaviors within the team context.
    a. Arts based innovation training increases an individual's collaborative behaviors and collaborative skills, as compared with traditional innovation training.

3. Arts based learning influences the quality of the final product developed by the team.
    a. Arts based innovation training, compared to traditional innovation training, will result in a team producing a more innovative and feasible product.

Both high school students and the early career STEM professionals maintained the same schedule, while there were differences in the activity flows of the curriculum between the control and treatment group to account for replacement of 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 used in the treatment (see **Table 1**).

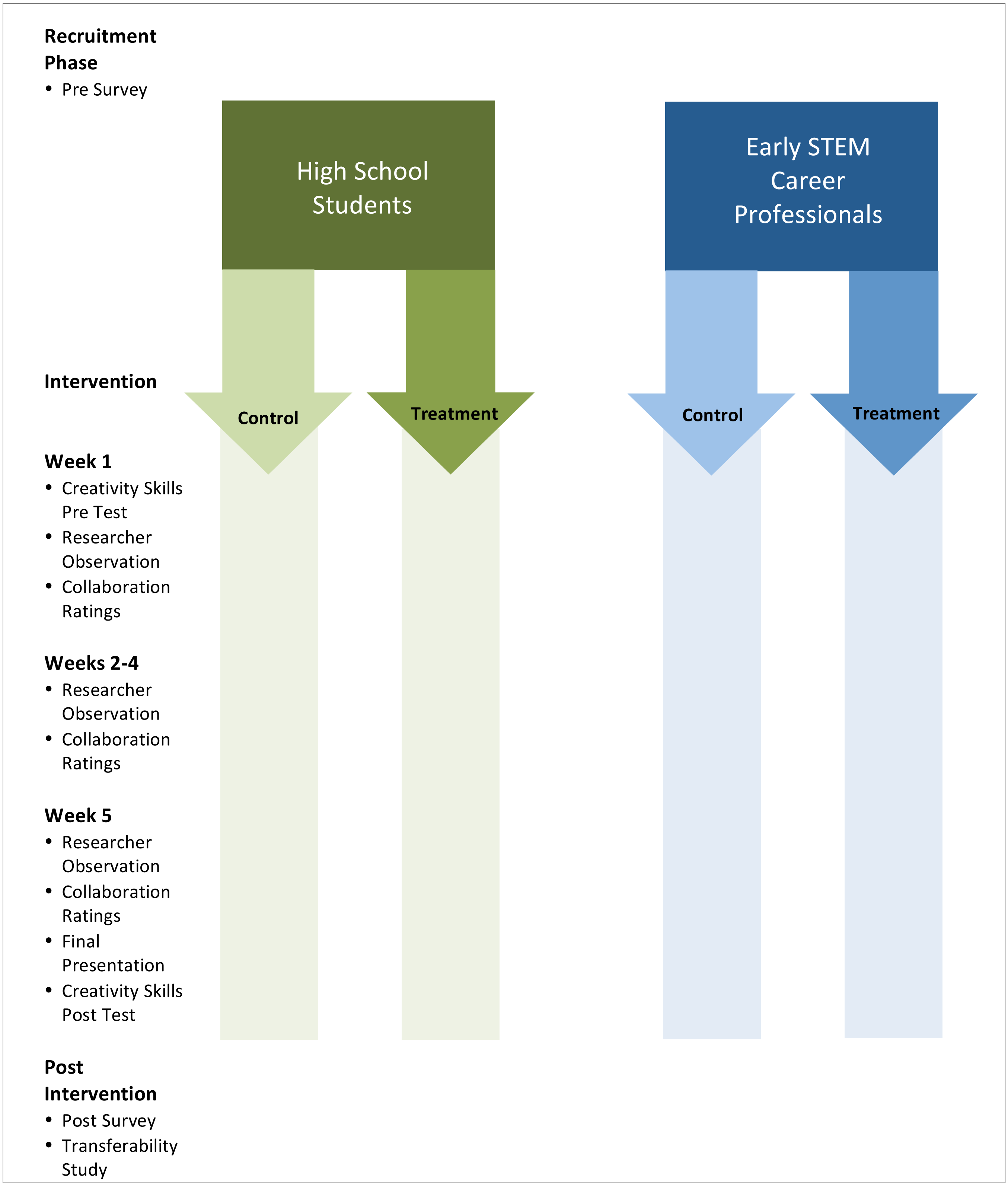
Table 1: Research Curriculum Schedule

	Morning- Treatment Group	Afternoon- Control Group
R1	1. Welcome and overview 9:00am- 9:15am	1. Welcome and overview 1:30pm- 1:45pm
	2. Creativity Skills Test 9:15am- 9:30am	2. Creativity Skills Test 1:45pm- 2:00pm
	3. Introduction to Challenge 9:30am- 10:30am	3. Introduction to Challenge 2:00pm- 3:00pm
	4. Introduction to Innovation 10:30am- 10:50am	4. Introduction to Innovation 3:00pm- 4:15pm
	5. Metaphorming activity 11:05am- 12:50pm	5. Innovation Tools & Their Use 4:15pm- 5:15pm
	6. Wrap up 12:50pm- 1:00pm	6. Wrap up 5:15pm- 5:30pm
R2	1. Welcome and review 9:00am- 9:15am	1. Welcome and review 1:30pm- 1:45 pm
	2. Introduction to Opportunity 9:15am- 9:30am	2. Introduction to Opportunity 1:45pm- 2:00pm
	3. Information Gathering/Enrichment #1 9:30am- 10:15am	3. Expert Panel 2:00pm- 2:30pm
	4. Expert Panel 10:15am- 10:45am	4. Q&A with Expert Panel 2:30pm- 3:00pm
	5. Q&A with Expert Panel 11:00am- 11:30am	5. Brainstorming Three Opportunity Sources 3:00pm- 3:30pm
	6. Problem/Opportunity Workshop 11:30am- 11:45am	6. Identifying Opportunities and Building Shared Goals 3:45pm- 4:40pm
	7. Problem/Opportunity Selection Workshop 11:45am- 12:50pm	7. Describe What Problems/Solutions Your Team Selected 4:40pm- 5:10pm
	8. Wrap up 12:50pm- 1:00pm	8. Wrap up 5:10pm- 5:30pm

R3	1. Welcome and review 9:00am- 9:05am 2. Opportunity Selection 9:05am- 9:50am 3. Ideation Cycle 9:50am- 10:55am 4. Ideation Cycle, part two 10:55am- 11:40am 5. Idea Enrichment and Refinement 11:40am- 12:55pm 6. Wrap up 12:55pm- 1:00pm	1. Welcome and review 1:30pm- 1:45pm 2. Vision 2025 Exercise 1:45pm- 2:45pm 3. Solution Selection 2:45pm- 3:30pm 4. Researching Problem/Solution Statements 3:45pm- 4:45pm 5. Scoring Enhanced Solutions 4:45pm- 5:10pm 6. Wrap up 5:10pm- 5:30pm
R4	1. Welcome and Review 9:00am- 9:05am 2. Concept Selection 9:05am- 9:40am 3. Rehearsing Idea Session 9:40am- 11:30am 4. Creating Business Cases 11:30am- 12:55pm 5. Wrap up 12:55pm- 1:00pm	1. Welcome and review 1:30pm- 1:45pm 2. Prioritize Product/Service Concepts from solutions 1:45pm- 3:15pm 3. Concept Feasibility and Market Enhancement 3:30pm- 4:30pm 4. Begin Business Case Development 4:30pm- 5:15pm 5. Wrap up 5:15pm- 5:30pm
R5	1. Welcome and Review 9:00am- 9:05am 2. Completing Business Cases 9:05am- 9:45am 3. Presentation Development 9:45am- 10:40am 4. Casting and Rehearsing the Presentations 10:40am- 11:45am 5. Gate Presentations 11:45am- 12:45pm 6. Creativity Skills Test 12:45pm- 1:00pm	1. Welcome and review 1:30pm- 1:35pm 2. Iteration & Business Case Review Discussion 1:35pm- 1:50pm 3. Write Clear and Comprehensive Concept Statements 1:50pm- 2:10pm 4. Sub-groups Work on Business Cases and Gave Presentations 2:10pm- 4:15pm 5. Gate Presentations 4:15pm- 5:15pm 6. Creativity Skills Test 5:15pm- 5:30pm

Note: There was a 15 minute break roughly in the middle of each four-hour session, for both control and treatment groups.

Figure 1: Study Design and Methods Visual Representation



Methods

The study used an experimental design with treatment and control groups; control groups were included to provide a comparison to treatment group participants who experienced the arts-based activities. Both groups experienced a STEM innovation workshop; however, the treatment group also experienced the creative thinking activities, allowing for an understanding of the added value of the arts-based activities to the workshop experience. The study also incorporated mixed methods; while the focus was on quantitative data, critical qualitative data were also captured to better understand the individual experience of participating in the Innovation Challenge (see **Table 2**).

Data were collected at two locations: the EcoTarium in Worcester, Massachusetts, and Balboa Park in San Diego, California. Furthermore, there were two main audiences the study focused on: 1) high school students, and 2) adults who were at an early stage in their STEM careers (early career STEM professionals). All participants in the Worcester cohort were high school students, and all of the participants in the San Diego cohort were early career STEM adults. A total of 65 individuals participated in the complete course of 5 Worcester workshops, and a total of 69 individuals participated in the complete course of 5 San Diego workshops. While participants were aware that they were participating in an NSF-funded study, they were not aware that it was an experimental study or that it was looking at arts-based approaches to innovation.

In looking at attendance rates for the Worcester cohort, there was an interesting effect - the treatment group saw 32 of the 34 initial participants complete the five sessions, an attrition rate of 6%; while the control group saw 33 of the initial 38 participants complete the five sessions, an attrition rate of 13%. The San Diego groups saw a similar pattern of attrition: 37 of the 40 initial participants in the treatment group completed all five sessions, an attrition rate of 8%; while the control group saw 32 of the initial 36 participants complete the five sessions, an attrition rate of 11%.

For both cohorts, the attrition rate was considerably higher for the control group than for the treatment group, though this occurred to a greater degree in Worcester. In each cohort, the greater level of attrition among the control groups was manifest by week two. While data were not collected during this study about why participants were no longer continuing with the program, one possible explanation is that the control and treatment approaches were engendering a different level of engagement.

Multiple methods were used as part of this large research plan, including:

1. Recruitment Survey
2. Pre- and post-intervention written questionnaires;
3. Creative thinking skills assessment;
4. Observations;
5. Follow-up transferability surveys with a subset of participants; and
6. Scoring of innovation team products.

See the Appendices of the report for the related instruments.

Table 2: Summary of Methods

Method	When Administered	Source of Approach, Instrument or Items
Recruitment Survey (Demographic Variables)	Before Participation (Pre)	Researcher-generated based on project needs.
Pre Workshop Survey (Currently Level of Arts and STEM participation)	Before Participation (Pre)	Modified from Slover-Linnett's evaluation of the AoSL incubators.
Creative Thinking Skills Test Survey	Before and After Participation (Pre/Post)	An activity developed by Harvey Seifter, modified from Runco and Basadur's (1993) article Assessing Ideational and Evaluative Skills and Creative Styles and Attitudes, and scored on a rubric developed by Harvey Seifter and AVC.
Slover-Linnett Creative Process Perceptions Survey	Before and After Participation (Pre/Post)	Scale developed by Slover-Linnett (AoSL evaluator) to look at perceptions of the creative process. It worked well on the evaluation pretest, providing a significant range of opinions.
Basadur's Creative Problem Solving Profile (CPSP) Survey	Before and After Participation (Pre/Post)	A modified version of Basadur, Graen, and Wakabayashi's (1990) Creative Problem Solving Profile (CPSP) Inventory, which measures preference for different stages in the creative process, differentiating how individuals prefer to gain and use knowledge. They propose four stages to an individual's creative process.
Critical Thinking Survey	Before and After Participation (Pre/Post)	Drawn from Basadur and Finkbeiner's (1985) scale on preference for ideation and tendency for premature critical evaluation of ideas, this scale was used in Runco and Basadur's (1993) study on ideation and evaluative thinking change during training.

Creative Competencies Survey	Before and After Participation (Pre/Post)	Adapted from an abridged version of the Epstein Creativity Competencies Inventory for Individuals (ECCI-i), developed by Epstein, Schmidt, and Warfel (2008). There are four measurable, trainable competencies: capturing (preserving new ideas as they occur), challenging (taking on difficult tasks), broadening (seeking knowledge and skills outside one's current areas of expertise), and surrounding (seeking out new stimuli or combinations of stimuli).
Self-rated Common Purpose and Collaboration Survey	During Participation (Each Week)	Eleven traits of collaborative behavior, identified by the project director, were drawn from the collective work of Hackman (2002), Katzenbach and Smith (1993), Sawyer (2007), Senge and Scharmer (2001), Thota and Munir (2012), Moss Kanter, Heifetz and Linsky (2002). Individuals were asked to rate their team each week; the same traits were included for the Observed Behaviors method.
Observed Behaviors	During Participation (Each Week)	Eleven traits of collaborative behavior, identified by the project director, drawing from the collective work of Hackman (2002), Katzenbach and Smith (1993), Sawyer (2007), Senge and Scharmer (2001), Thota and Munir (2012), Moss Kanter, Heifetz and Linsky (2002). The researchers counted instances of the various behaviors during collaborative tasks each week; the same traits were included for the Self-rated Common Purpose and Collaboration Survey.
Team Innovation Outcomes Assessment Panel	After Participation (Post)	Expert panelists from the Product Development Management Association's selection committee of Outstanding Corporate Innovation Awards viewed teams' final products (business case, PowerPoint presentations, video of concept presentation, and video of responses to questions. The panel developed a rubric with seven elements, rated each team independently on these elements, then calculated a final score for each team.

Recruitment Survey

As the team was attempting to recruit individuals who met a defined set of criteria, potential recruits were asked to fill out a questionnaire to find out more about their background and relevant experiences. The questionnaire asked about involvement with STEM activities, current employment status, current student status, gender and age. The questionnaire also asked how participants found out about this Innovation Challenge research project. The questionnaire captured the contact information for participants in order to email information and an invitation to the pre workshop survey. This questionnaire was posted on a public webpage using the SurveyMonkey web-based platform to provide access to the potential recruits.

Pre Workshop Survey

Once accepted into the Innovation Challenge (i.e., the workshop), participants were asked to complete a survey prior to the Challenge start, in order to learn more about the participant and so that responses to this pre-survey could be compared to the responses to the post-survey after completing the Innovation Challenge. The questions were broken up into sections that directly correlated to the main hypotheses tested within the study. A link to the survey was sent via email to participants and the survey was hosted on a private webpage on the SurveyMonkey web-based platform. See Appendix A.

Question 1 collected information about an individual's prior connections with art and science. This information was mostly used to sort individuals into teams so that the teams had similar average scores for art and science experience, to reduce bias between teams.

Question 2 focused on creative thinking. The question was adapted from an abridged version of the Epstein Creativity Competencies Inventory for Individuals (ECCI-i), developed by Epstein, Schmidt, and Warfel (2008). Slover-Linett used this scale with some success within the pre-survey for incubator participants.

Question 3 was adapted from the Norton (1975) Tolerance for Ambiguity Scale. The AVC research team took items from the "problem-solving" and "philosophy" subscales; there were six other subscales. Tolerance for ambiguity may be a significant independent variable for participants, given the nature of the control and treatment curriculum.

Question 4 was developed by Slover-Linnett to look at perceptions of the Creative Process. It seemed to function well on their pretest with a significant range of opinions

Question 5 was designed to learn more about critical thinking skills. Drawn from Basadur and Finkbeiner's 1985 scale on preference for ideation and tendency for premature critical evaluation of ideas, this scale was used in Runco and Basadur's (1993) study on ideation and evaluative thinking change during training.

Question 6 was drawn from a modified version of Basadur, Graen, and Wakabayashi's (1990) Creative Problem Solving Profile (CPSP) Inventory, which measures preference for different stages in the creative process, differentiating how individuals prefer to gain and use knowledge.

Participants were then asked if they identified as an innovator, and prompted to give their own personal definition of innovation. The survey concluded with a few additional demographic questions, like ethnic origin and highest level of education completed.

Pre Workshop Creative Thinking Skills Test

Participants in the Innovation Challenge were asked to complete an "Innovation Warm-up" exercise, at the start of the first day of the workshop. The task included defining problems and choosing a problem related to the Innovation Challenge as described by the promotional material, then defining solutions and choosing a solution to the previously chosen problem. Participants had 15 minutes to complete the skills test. This test was taken with paper and pencil. See Appendix F and Appendix G.

These tasks were derived from concepts similar to the challenges noted in Runco and Basadur's (1993) article on Assessing Ideational and Evaluative Skills and Creative Styles and Attitudes. The solutions were scored in a complex rubric including the quantity of problems and solutions identified, the breadth of problems and solutions, and the motivations for choosing a particular problem to focus on. The rubric can be seen in Appendix I.

Workshop Observations

Data collectors observed participants each week of the Innovation Challenge. The purpose of this approach was to document examples of individual collaborative behaviors in team settings, across the five research sessions or weeks. AVC scheduled at least two data collectors for each workshop week; AVC team members collected some data, but also hired local individuals who had experience observing behavior in an experiment setting. Due to the constraints of the number of groups in each workshop and the number of data collectors it was impossible to observe each group during all activities and group discussion periods. It was therefore necessary for data collectors to rotate between groups during the workshop sessions. See Appendix C.

Data collectors observed the individuals on one team for a period of time, usually between 10 and 30 minutes, during a group activity or discussion period. Since the behaviors focused on collaboration, participants were not observed during presentations by faculty or when individuals were working on their own. The AVC and Art of Science Learning teams developed a list of behaviors to be observed which corresponded to the main hypotheses tested within the study. Data collectors recorded behaviors displayed by individuals on the team during the observation period, and additionally recorded any unusual or noteworthy activity outside of the list of behaviors to observe. Observations were recorded on paper data sheets with pen or pencil. At the end of the predetermined observation period the data collectors moved on to the next team and began with a new observation period. Each session was discussed at length before the sessions to determine when the participants would be observed, for how long, and when data collectors would switch between teams. With two data collectors and four teams, switching once within an observation period would mean that all four teams were observed during an activity or observation period.

Team Collaboration Ratings

At the end of each workshop session participants were asked to rate their team on a series of behaviors that directly aligned with the collaborative behaviors recorded by data collectors in the workshop observation sheet. This was an attempt to triangulate a realistic depiction of an individual's collaboration and participation in the Innovation Challenge. Individuals were asked to rate their team's performance based on a series of behaviors on a scale from 1 to 7 points, and then were asked to give their team an overall rating between 1 and 7 points. The surveys were taken on iPads through the SurveyMonkey web-based platform. There were 4 to 8 iPads available during the workshops, so individuals took turns filling out the survey before submitting their survey and passing the iPad on to the next team member.

Post Workshop Creative Thinking Skills Test

Just before the close of the last day of the Innovation Challenge, participants were asked to again complete the exercise they had done on their first day of the workshop this time described as an "Innovation Wrap Up." The format of the exercise was exactly the same as the first session: the participants in both cohorts were asked to address access to affordable and healthy food, rather than the topics these cohorts had been working on over the previous weeks. See Appendix H.

Post Workshop Survey

Approximately one week after completing the Innovation Challenge, participants were sent a link to a Post Workshop Survey, which was hosted on a private webpage through the SurveyMonkey web-based platform. This survey had the exact same questions as the Pre Workshop Survey, Questions 2 to 6, in order to compare the responses of individuals before and after the workshop experience, and to compare the responses between the control and treatment groups. See Appendix B.

Again, like the Pre Workshop Survey, individuals were asked if they self-identified as an innovator; however, this time individuals were also asked if their definition of innovation had changed since participating in the workshop. Finally, participants were also asked to rate each individual member of the team, on a scale from 1 to 7, based on their contributions over the five sessions.

Transferability Survey

About four months after completing the Innovation Challenge AVC sent a follow up web survey to all participants to explore the long-term effects of their experience. The survey was hosted on a private webpage through the SurveyMonkey web-based platform. Participants were asked whether they had been thinking about the workshop since its completion, if the workshop had changed how they think about the creative thinking process, and whether individuals thought they would be able to use some of the techniques learned during the workshops in their professional and personal life. Completion of the Transferability survey was not mandatory; therefore, the total number of individuals who participated in this method is lower than the total number of individuals who participated in the workshops. See Appendix E.

Team Innovation Outcomes Assessment Panel Ratings

The review of the final team innovation outcomes was conducted by a panel composed of three members of the selection committee of the Product Development Management Association's (PDMA) Outstanding Corporate Innovation Awards, including that committee's founding and current Chairs. The panel, consulting with the project and research teams, developed an assessment rubric identifying and weighting seven measures to gauge the quality of the innovation outcomes, including team innovation outputs and work products. They subsequently applied the rubric to each team's product, process and service solution concepts developed by the teams. The panelists met in person over two days at the Kelley School of Business at Indiana University to review and discuss the PowerPoint presentations created by each team about its innovation, pre-recorded videos of each team's 5-minute concept presentation, and pre-recorded videos of each team's responses to a standardized set of questions. Ahead of the panel meeting (but after the panel's completion of work on the assessment rubric), the panelists also received the business cases (see Appendix J) created by each of the teams for their advance review; panelists were asked not to discuss these materials with their colleagues ahead of the meeting. Taken together, these elements (business case, PowerPoint presentations, video of concept presentation, and video of responses to questions) formed the basis for the panel's overall assessment of each team's innovation outcomes. The reviewers did not know which of the 16 groups were in the control or treatment condition, and the order of teams within each condition (i.e., control and treatment) was randomized. See Appendix K.

Limitations

1. Number of research sites: Initially it was intended to have three research sites (Chicago, Worcester, and San Diego), and have each site run a 5-week Innovation Challenge. Unlike in the final design, each site would have a cohort of high school students and of early STEM career professionals, though these two groups would not be mixed. For example, the high school control group would meet Saturday morning, the early STEM career group Saturday afternoon, the high school treatment group Sunday morning, and the early STEM career treatment group Sunday afternoon.

Recruitment for the Chicago incubator was low, especially among STEM professionals, and we were concerned that the groups recruited would not result in sample sizes large enough to analyze. The Chicago Innovation Challenge was indefinitely postponed, and we made corresponding changes to the sample make-up in Worcester and San Diego. The changes allowed the team to reduce the sample size, as we only had one population type per site. While this conflates the site with the population type, it allowed recruitment to be successful within those sites.

2. Data collection locations/need for local data collectors: Due to the time and financial factors of having multiple AVC employees traveling for 10 weekends, AVC recruited local data collectors in Worcester, Massachusetts, and San Diego, California to collect observation data during the Innovation Challenge. AVC found local data collectors who came with good recommendations from peers in the field and who were experienced in observing behaviors in informal learning environments. An AVC team member trained two local data collectors during the first two weeks in San Diego and the first three weeks in Worcester on using the observation and collaboration rating instruments and answering basic questions about the flow of the work day. An AVC team member was available by phone and text message during the last weeks of the intervention in case of emergency or need for clarification.

Therefore, including three AVC team members who collected observation data, there were a total of seven data collectors for one instrument. It is possible that having more data collectors could introduce more error into the data due to different definitions and interpretations of behaviors. To mitigate discrepancies all data collectors were encouraged to compare notes throughout the day and discuss questions about whether certain gestures or language used by participants did indeed qualify as specific behaviors according to the instrument.

3. Placing people purposefully into groups: Putting people into the control and treatment groups, while being beneficial for spreading the two constructs (art and science) out, may have had some residual effect on the findings. A main purpose of the study was to compare the treatment and control groups within each of the two cohorts (high school students, early career STEM professionals), to see if being exposed to the arts-based approach made a difference in the outcomes. Given that comparison, it was important to counterbalance the control and treatment groups so that the characteristics of each group did not skew in a certain direction that could impact the results. As researchers, it was also unclear how diverse the groups would be; if they were very diverse then it would be important to spread that diversity evenly across the control and treatment groups, and then also within the four groups in each of these cohorts. Students were counterbalanced by accounting for an “art score,” a “science score,” and a “creativity score;” the average scores for each were matched as closely as possible, so these three main scores mainly drove where individuals were placed (which cohort, then which group within each cohort). While this served the purpose of counterbalancing the effect of these variables on the results, there may have been some residual effect to making sure the groups were spread evenly along these variables. Said another way, there may have been an intangible benefit to having groups be more similar to each other that affected the results.

4. Attrition during the data collection: There was a strict no absence policy for participation in the Innovation Challenge workshop. Any participant who missed one week of the workshop was not allowed to return for any following workshop day. The program facilitators felt that participants who missed a workshop day would fall too far behind in content understanding and group collaboration and could not be reintegrated to the group.

It is possible that participants who felt the Innovation Challenge was not meeting their expectations decided to drop out of the program. Those individuals who did not perceive the Innovation Challenge to be beneficial for them would have likely showed no change in their behaviors and skills throughout all methods of data collection, Pre Survey to Post Survey, Collaboration Ratings, Observations, etc. This could possibly skew the data as we only have responses and rates of change for participants who completed the entire intervention. This is a consequence of the nature of the intervention designed as a workshop, not as a mandatory experimental design where participants must complete all workshop days.

5. Using adolescent curriculum for both groups. In order to be consistent and allow for a comparison between the high school students and adults who were at an early stage in their STEM career, the same curricular approach was used for both cohorts. The curriculum used in this study was specifically designed for use with adolescents, and while there was the possibility that employing a student-focused curriculum could be experienced differently by the early career STEM professionals it was deemed necessary by the researchers in order to compare the utility of the approach with both cohorts. It is possible that some of the lack of findings among the early STEM professionals may result from the curriculum having been developed more for the adolescents. Further study to determine whether adult findings would change with the substitution of a curriculum specifically designed for use with adults would be valuable.

Sampling and Characteristics of the Sample

In the original plans for the Innovation Challenge workshops each location would have a cohort of high school student participants and a cohort of early career STEM professional participants. Because of difficulties in recruitment of early career STEM professional participants, in Worcester the project directors and AVC decided to cancel the adult workshop in Worcester and run only the high school student program, then run only the early career STEM professionals program in San Diego.

High School Students

The Art of Science Learning team at the host site the EcoTarium in Worcester, led by AoSL's Worcester Incubator Director Joyce Kressler, conducted recruitment of participants, reaching out to contacts in the community to raise awareness about the workshop. Project community partners included regional public and private schools, nonprofit organizations, colleges and universities, informal learning centers, parent organizations, businesses and educators. Altogether, AoSL contacted more than 15 high schools (for example, Worcester Technical High School and Doherty High School), more than 10 community colleges and universities (for example, Worcester State University and University of Massachusetts Medical School), 6 non-profit organizations (for example, the Boys and Girls Club of America), 7 STEM-related companies (for example, Intel), and more than 10 relevant professional organizations (for example, Massachusetts Biomedical Initiatives). Information and invitations to register for the workshop were sent via email to a contact at each school or institution, and the AoSL team at the EcoTarium also made phone calls to certain partners where applicable. Additionally, the EcoTarium promoted the Worcester Innovation Challenge through a posting on their Facebook page that was paid for by funds from the Art of Science Learning grant.

Prospective participants in the Innovation Challenge workshop were asked to fill out a short questionnaire about their experience with STEM (Science, Technology, Engineering, Math) subjects and their current involvement with creative or artistic pursuits. Recruiters focused their efforts to find participants who had some level of interest or participation in the STEM fields, but it was not necessary that a participant be actively involved in any creative or artistic endeavor. The questionnaire also collected information about the grade level and high school the participant attended, information that would be used to group participants into teams so that people who already knew each other would not be on the same teams. Recruitment focused on high school students in 10th and 11th grades; however, students in 9th and 12th grades were accepted to the Worcester Innovation Challenge.

Participants were also required to submit two electronic consent forms in order to participate in the Worcester Innovation Challenge: a form consenting for themselves, and a second form with the assent of their parent or guardian. Participants who did not submit these two separate forms were not allowed to complete the Pre Workshop Survey per IRB regulations and therefore could not continue in the recruitment process.

By the end of the recruitment period there were more students who had registered for the Worcester Innovation Challenge workshop than could participate; a total of 190 applications were received, some incomplete, and only 88 participants could be accepted to the program. Participants were taken on a first come first served basis, then divided by their schools and grade into eight temporary teams of eleven students with the understanding that a few students might not show the first day, or would drop out after the first workshop session. The temporary teams were configured in a way that no team would have more than one participant from the same school and grade; however, while teams did have more than one participant from the same school, they were from different grades. Consideration was also given to participants who had requested participating in either the morning or afternoon workshops due to scheduling or transportation conflicts. Other than these stipulations, participants were randomly assigned to the control group (afternoon session) or treatment group (morning session). Participants who attended a school with already considerable representation on the teams were contacted and informed that they would be unable to participate in the Worcester Innovation Challenge.

Participants were then sorted based on their responses to the Pre Workshop survey about their experience with art and science education and their “creativity score” (a composite score of specific questions from the Pre Workshop Survey). Teams were configured to have very similar overall averages of their scores for art, science and creativity, without any overlapping of high school and grade level. It was critical to maintain these average scores, which did not have a statistically significant difference, in order for the teams to be comparable between control and treatment groups.

On the first day of the workshop participants were resorted into groups if individuals on the same team had personal relationships with each other, which could not have been foreseen by the planning team. Teams were also resorted in the event that multiple participants temporarily placed on a certain team decided not to participate, to even out the average size of each team. However, once individuals were officially placed on a team during the first hour of the Worcester Innovation Challenge, individuals were not allowed to switch to a different team at any point during the length of the Challenge.

The Innovation Challenge workshops for the high school student cohort were held on consecutive Sundays from October 26th, 2014 through November 23rd, 2014. Each half day session ran for a period of four hours; the morning session was held from 9:00 am to 1:00 pm and the afternoon session was held from 1:30 pm to 5:30 pm. Participants in the Worcester workshop were offered a stipend of $250, which they would receive after attending all five workshop dates and completing the post workshop survey. The workshops were held at the EcoTarium, a science museum and nature center in Worcester, Massachusetts.

By week five of the Worcester Innovation Challenge a total of 65 individuals participated in the cohort. This means that there was some attrition throughout the five weeks of the Challenge; however, the majority of individuals who dropped out of the program did so between week one and week two. As noted above, the attrition rate was considerably higher for the control group than for the treatment group. The treatment group saw 32 of the 34 initial participants complete the five sessions, with an attrition rate of 6%; while the control group saw 33 of the initial 38 participants complete the five sessions, with an attrition rate of 13%.

There were more female participants (68%) than male participants (32%), with all participants in the Worcester Innovation Challenge between the ages of 15 and 18 years old (see **Table 3**). Almost all of the participants were full-time students (95%) and came from more than 20 different high schools in the area. The majority of participants were not employed (85%), though some were employed part-time (12%). The largest single group of participants reportedly identified with the Caucasian or White ethnic category (41%), with the next most commonly identified categories being Asian (15%) and African American or Black (14%). A smaller percentage of participants identified as Hispanic or Latino (8%) and American Indian or Alaska Native (1%). Some participants preferred not to answer (11%) and some chose “Other” and wrote in how they identified themselves. For example, some participants wrote:

Native America, Portuguese, African American, French Canadian, etc.
Arabic

Indian
European and African
I am half Caucasian and half Pakistani

Table 3: Demographics for High School Student Participants

Characteristic	Control (n=33)	Treatment (n=32)	Total (n=65)
Gender			
Male	27%	38%	32%
Female	73%	62%	68%
Age Category			
15 to 18	100%	100%	100%
Ethnic Category			
Caucasian or White	42%	42%	41%
African American or Black	21%	6%	14%
Asian	6%	25%	15%
Hispanic or Latino	6%	9%	8%
American Indian or Alaska Native	0%	3%	1%
Other	9%	12%	11%
Prefer not to answer	15%	3%	9%
Current Level of Education			
Still enrolled in high school	85%	97%	91%
GED	3%	0%	1%
Did not answer	12%	3%	8%
Student Status			
Part-time student	0%	6%	3%
Full-time student	97%	94%	95%
Did not answer	3%	0%	1%
Grade Level			
9^{th}	6%	0%	3%
10^{th}	48%	44%	46%
11^{th}	39%	31%	35%
12^{th}	6%	25%	15%
Employment Status			
Not employed	88%	81%	85%
Employed part-time	9%	16%	12%
Did not answer	3%	3%	3%

(Table 3 continued below)

Table 3: Demographics for High School Student Participants continued

Characteristic	Control (n=33)	Treatment (n=32)	Total (n=65)
School Attendance			
Worcester Technical High School	18%	19%	18%
University Park Campus School	18%	3%	10%
Doherty Memorial High School	3%	16%	9%
North High School	6%	9%	8%
Bancroft School	3%	12%	8%
South High Community School	9%	3%	6%
Burncoat High School	9%	0%	5%
Wachusett Regional High School	3%	6%	5%
Shrewsbury High School	6%	0%	3%
Massachusetts Academy of Math and Science	3%	3%	3%
Lincoln Sudbury High School	6%	0%	3%
Plainfield High School	0%	6%	3%
Hopkinton High School	3%	3%	3%
Advanced Math and Science Academy Charter	0%	6%	3%
Worcester Academy	0%	6%	3%
Saint John's High School	0%	3%	1%
Hopedale Junior-Senior High School	3%	0%	1%
Quinebaug Middle College	3%	0%	1%
Northampton High School	0%	3%	1%
Holy Name Junior Senior Central Catholic	3%	0%	1%
Auburn High School	3%	0%	1%

Early Career STEM Professionals

Dr. Nan Renner, Director of the Art of Science Learning San Diego Incubator and the AoSL team conducted recruiting for the San Diego Innovation Challenge. The teams reached out to contacts in the community to raise awareness about the workshop, such as nonprofit organizations, educators and other educational institutions. Information about the San Diego Innovation Challenge was distributed via the Balboa Park Learning Institute e-newsletter, which has 1,800 subscribers. The team in San Diego emailed approximately 150 educators from San Diego State University, University of California San Diego, and the community colleges in the area. Additionally, they reached out to about 50 educators from Balboa Park and contacted more than 100 additional individuals from their personal networks.

Specific criteria for selection included current employment in a STEM-related professional field or role (including STEM education), less than seven years of professional experience working in a STEM field, completion of at least two years of college education and professional competence in English. Two AVC researchers independently reviewed the information submitted in the questionnaire to determine eligibility for each potential participant. Each potential participant was labeled as "yes," "no," or "maybe" based on the criteria. In order to provide as diverse and balanced a group as possible, secondary criteria were also taken into account. These included age, whether or not potential participants were teachers or current students, and arts background. Also taken into consideration was availability; participants unable to commit to attending all of the sessions were not invited to participate. After each potential participant was categorized independently, the two researchers then compared and finalized the list of those invited to participate.

Participants for the Innovation Challenge workshop were asked to fill out a short questionnaire about their experience with STEM subjects (Science, Technology, Engineering, Math) and their current involvement with creative or artistic pursuits. Recruiters focused their efforts to find participants who were in the early stages of their career in the STEM field, however some participants who were accepted to the program did not work directly in the STEM field, and some participants did in fact work within the STEM field but were not in the beginning of their career. It was not necessary that a participant participate in any creative or artistic endeavor. The questionnaire also asked whether participants were students, employed part-time or full-time, or unemployed/retired.

Participants were required to submit an electronic consent form in order to participate in the San Diego Innovation Challenge. Participants who did not submit this form were not allowed to complete the Pre Workshop Survey per IRB regulations and therefore could not continue in the recruitment process. There were fewer obstacles for including and sorting teams in the San Diego Innovation Challenge because the participants were not minors, and therefore only had to complete one consent form.

By the end of the recruitment period there were more individuals who had registered for the San Diego Innovation Challenge workshop than could participate; a total of 175 applications were received, some incomplete, and only 88 participants could be accepted to the program. Participants were taken on a first come first served basis, then divided into eight temporary teams of eleven individuals with the understanding that a few individuals might not show the first day. Consideration was also given to participants who had requested participating in either the morning or afternoon workshops due to scheduling or transportation conflicts. Other than these stipulations, participants were randomly assigned to the control group (afternoon session) and treatment group (morning session).

Participants were then sorted based on their responses to the Pre Workshop survey about their experience with art and science education and their "creativity score" (a composite score of specific questions from the Pre Workshop Survey). Teams were configured to have an overall average of art score, science score and creativity score. It was critical to maintain these average scores, which did not have a statistically significant difference, in order for the teams to be comparable between control and treatment groups.

On the first day of the workshop participants were resorted into groups if individuals on the same team had personal relationships with each other, which could not have been foreseen by the planning team. Teams were also resorted in the event that multiple participants temporarily placed on a certain team decided not to participate, to even out the average size of each team. However, once individuals were officially placed on a team during week one of the Worcester Innovation Challenge, individuals were not allowed to switch to a different team at any point during the length of the Challenge.

The Innovation Challenge workshops for the early career STEM professional cohort were held on consecutive Saturdays from January 10th, 2015 through February 7th, 2015. The workshops were held at Balboa Park in San Diego, California. Each half day session ran for a period of four hours; the morning session was held from 9:00 am to 1:00 pm and the afternoon session was held from 1:30 pm to 5:30 pm. Participants in the Worcester workshop were offered a stipend of $500, which they would receive after attending all five workshop dates and completing the post workshop survey. The stipend for the San

Diego participants was significantly larger than the stipend for the Worcester participants- this was a purposeful decision made to give adults a greater incentive to continue to the end of the program.

By week five of the San Diego Innovation Challenge a total of 69 individuals participated in the cohort. This means that there was some attrition throughout the five weeks of the Challenge; however, the majority of individuals dropped out of the program week one. As noted above, the attrition rate was higher for the control group than for the treatment group. Researchers noted that 37 of the 40 initial participants in the treatment group completed all five sessions, with an attrition rate of 8%; while the control group saw 32 of the initial 36 participants complete the five sessions, with an attrition rate of 11%.

Due to the nature of the recruiting requirements for the San Diego Innovation Challenge, there were a wider variety of ages in this program, compared to Worcester (see **Table 4**). The majority of participants were young adults 19 to 25 years old (42%) or 26-30 years old (17%) in the beginning stages of their career. There were smaller percentages of adults, 31 to 40 years old (26%), 41 to 50 years old (7%), 51 to 60 years old (6%) and 61 to 70 years old (1%). There were still more women participants in the San Diego Challenge, like Worcester; however, the ratio of women to men was more even (59% women, 41% men).

The majority of participants reportedly identified with the Caucasian or White ethnic category (52%), with the next most commonly identified categories being Hispanic or Latino (19%) and Asian (16%). A smaller percentage of participants identified as African American or Black (4%) and Native Hawaiian or other Pacific Islander (1%). Some participants preferred not to answer (7%) and some chose "Other" and wrote in how they identified themselves. For example, some participants wrote in a more detailed description of their ethnic category such as:

Chicano
Brazilian
Also Hispanic, would not let me check more than one
European

The majority of participants were not currently attending a school (62%) but there were some participants who were full-time students (29%) or part-time students (9%). Of those individuals who were taking classes at the time of the San Diego Innovation Challenge 16% were enrolled in college or community college courses, and 22% were enrolled in graduate school. Those participants who were students at the time of the workshop attended a variety of schools in the San Diego area, including University of California, San Diego (17%) and San Diego State University (7%). Many participants had already completed a community college or technical certificate (9%), a college degree (43%) or a graduate or postgraduate degree (36%). A small percentage of participants (10%) reported their highest level of education as a high school diploma or GED.

Almost all participants were involved in careers that were STEM related (77%) or in some way related to the STEM field (20%). The majority of participants were employed either full-time (56%) or part-time (26%) with just a few participants reporting to be unemployed or retired (4%)

Table 4: Demographics for Early Career STEM Professional Participants

Characteristic	Control (n=32)	Treatment (n=37)	Total (n=69)
Gender			
Male	37%	43%	41%
Female	62%	57%	59%
Age Category			
19 to 25	44%	40%	42%
26 to 30	16%	19%	17%
31 to 40	22%	30%	26%
41 to 50	6%	8%	7%
51 to 60	12%	0%	6%
61 to 70	0%	3%	1%
Ethnic Category			
Caucasian or White	47%	57%	52%
African American or Black	3%	5%	4%
Asian	22%	11%	16%
Hispanic or Latino	12%	24%	19%
Native Hawaiian or other Pacific Islander	3%	0%	1%
Prefer not to answer	12%	3%	7%
Student Status			
Not currently a student	62%	62%	62%
Part-time student	12%	5%	9%
Full-time student	25%	32%	29%
Current Education Level			
College or community college	22%	11%	16%
Graduate school	16%	27%	22%
Not applicable	62%	62%	62%
Highest Level of Education			
High school/GED	12%	8%	10%
Community College/technical training	6%	11%	9%
College Degree (BA/BS)	47%	40%	43%
Graduate or Postgraduate Degree	31%	40%	36%
Did not answer	3%	0%	1%
Current STEM Professional?			
Yes	75%	78%	77%
No	0%	3%	1%
To some extent	25%	16%	20%
I’m not sure	0%	3%	1%
Employment Status			
Not employed and/or retired	9%	16%	13%
Employed part-time	28%	24%	26%
Employed full-time	59%	54%	56%
Did not answer	3%	5%	4%

(Table 4 continued below)

Table 4: Demographics for Early Career STEM Professional Participants continued

Characteristic	Control (n=32)	Treatment (n=37)	Total (n=69)
School Attendance			
University of California, San Diego	12%	22%	17%
San Diego State University	9%	5%	7%
Point Loma Nazarene University	3%	3%	3%
Southwestern College	0%	3%	1%
Miami University, Ohio	0%	3%	1%
National University	3%	0%	1%
California State University, Long Beach	0%	3%	1%
San Diego City College	3%	0%	1%
CUNY Graduate Center, New York, NY	3%	0%	1%
San Diego State University & University of California, Davis joint program	3%	0%	1%

Hypothesis 1 Findings: Creative Thinking Skills

Fundamentally, the research component of the Art of Science Learning project was designed to investigate whether participating in arts-based innovation training gives one an advantage over participating in more traditional innovation training of the type that one might encounter in an academic or workplace setting. Within this framework, our research was broken down into three primary hypotheses. The first one considered the relative advantage of arts-based innovation training on a range of creative thinking skills. The team broke this hypothesis down into a series of sub-hypotheses in order to better investigate each element.

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.

- **Hypothesis 1a: Arts based innovation training increases an individual's ability to employ divergent thinking over traditional innovation training.**
- **Hypothesis 1b:Arts based innovation training increases an individual's ability to employ convergent thinking over traditional innovation training**
- **Hypothesis 1c: Arts based learning influences individuals' critical thinking skills.**

As mentioned within the methods section, each of these sub-hypotheses was measured through a variety of methods. Detailed information on the underlying constructs of each of these scales can be found in the summary table of methods (see **Table 2).**

One of the areas where we found the most significant differences between groups and between cohorts was within the Creative Skills measure. Participants were asked to complete a brief "Innovation Warm-up" exercise at the start of the first day of the workshop, and a similar "Innovation Wrap-up" at the close of the final day of the workshop. Participants were asked 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). A different Innovation Challenge was used for the second use of the exercise to prevent any practice effects. Participants had 15 minutes to complete the skills test. These tasks were derived from concepts similar to the challenges noted in Runco and Basadur's (1993) article on Assessing Ideational and Evaluative Skills and Creative Styles and Attitudes. A rubric that included the skill categories listed below was created for the scoring of this test. The rubric was designed to investigate the following creative thinking skills, and include the type of skill it examined:

Skill 1: How many distinct problems were identified? (Divergent)
Skill 2: How many idea clusters do those problems represent? (Divergent)
Skill 3: How clear is the problem statement as related to the challenge? (Convergent)
Skill 4: How many reasons given for why the individual chooses that problem? (Convergent)
Skill 5: How many distinct solutions were generated? (Divergent)
Skill 6: How strong is the solution statement? (Convergent)
Skill 7: How many reasons/evidence statements given for selection of the problem? (Convergent)
Skill 8: How many reasons/rationales given for choosing solution? (Convergent)

Skill 9: How specific is what the participant proposes to do? (Convergent)
Skill 10: How specific as to how the participant proposes to enact their solution? (Convergent)
Skill 11: How many specific idea clusters do these solutions represent? (Divergent)

Differences Within groups

Our core objective was to determine whether or not the type of innovation training individuals received impacted their creative thinking skills. Before we could compare the impact of training between the control and treatment groups, we needed to compare the impact of the training on each group individually.

As shown in **Table 5** below, the high school student treatment group showed statistically significant increases from pretest to post test within 6 of the 11 creative thinking skill variables. For the control group, there were no gains on any variable after the training; in fact, the high school control group had higher pretest scores within the critical thinking variables and 3 of the creative thinking skills when compared with their post-test scores.

A striking pattern emerged for the high school students: out of the 13 total variables that showed significant differences, only one of the two groups (control or treatment) showed a significant difference. Furthermore, 12 of these 13 variables showed a positive result in the direction of the treatment group. For example, the high school student treatment had 7 variables that showed a significant increase from pre to post, and none of these were significantly different for the control group; treatment increased, control stayed the same. Likewise, the high school control group had 5 variables that showed a significant decrease from pre to post for the high school control group, yet there was no significant difference for the treatment group; treatment stayed the same, while control decreased. These results strongly suggest that in addition to any beneficial impact of arts-based learning on specific creative thinking skills, arts-based learning may have the capacity to overcome and neutralize any negative impact of traditional innovation training on high school student creative thinking. It will be interesting to further investigate this possible effect, as well as to consider whether there are any positive impacts of traditional innovation training on other areas we did not measure, such as a potential increase in content knowledge about innovation. This possible impact merits further investigation. It would also be interesting to consider whether there are any positive impacts of either arts-based or traditional innovation training on other areas we did not measure, such as a potential increase in content knowledge about innovation.

The high school treatment group showed no perceivable gain on four of the creative thinking skills or on the critical thinking and creativity self-report scales; the increase was only measured on the creative thinking skills test, which suggests the possibility that arts-based training specifically has an impact on the type of skills this test was designed to gauge: the ability to identify a problem, articulate potential solutions, and identify a solution and articulate a rationale for that solution. The breadth and specificity of problems and solutions described are also evaluated within this assessment. It is also possible that despite efforts to balance the groups with regard to independent variables such as prior arts experience, science experience, and creativity scores, the control group entered with a higher level of creative skills, and thus showed no change; or that the creative skills assessment, with a scoring rubric developed after the implementation of the assessment, is in some unknown way biased. Nonetheless, the simplest explanation is that the arts-based training increases the creative thinking skills of high school students.

The results from the early career STEM professionals are less defined. As in the high school treatment group, but to a lesser degree, the early career STEM professionals treatment group shows some increases in creative thinking skills. They show no change in the critical thinking skills measures. On one self-report scale, Creativity 1, the early career STEM professionals treatment group had statistically significantly higher scores on the pre-test. As we did not expect them to lose creativity over the course of the training, it is unclear what this finding means. The early career STEM professionals control group showed little impact from the training, with the exception of increases in two creative skills: number of solution statements generating, and number of idea clusters represented by these solutions.

Table 5: Summary Table of Individual Creative Thinking Skills Scores (including Critical Thinking)

Variable	High School Students Treatment	High School Students Control	Early Career STEM Professionals Treatment	Early Career STEM Professionals Control
Critical Thinking 1	--	Pretest higher	--	--
Critical Thinking 2	--	Pretest higher	--	--
Mini-ECCI		Post test higher		
CPSP				
Creative Thinking Skills:		--		--
Skill 1	Post test higher		Post test higher	
Skill 2	Post test higher	--	--	--
Skill 3	Post test higher	--	Post test higher	--
Skill 4	--	Pretest higher	Post test higher	--
Skill 5	Post test higher	--	--	Post test higher
Skill 6	Post test higher	--	--	--
Skill 7	--	Pretest higher	--	--
Skill 8	--	Pretest higher	--	--
Skill 9	Post test higher	--	--	--
Skill 10	--	--	--	--
Skill 11	Pretest higher	--	--	Post test higher

Note: See pages 37-38 above for explanation of Skill 1 through Skill 11.

Differences Between groups

This section will focus on the differences between the control and treatment groups, organized within the sub-hypotheses articulated above. The four tables below address the main Hypothesis 1 (see **Table 6**) as well as sub-hypotheses 1a (see **Table 7**), 1b (see **Table 8**), and 1c (see **Table 9**).

For the high school student cohorts, these tables showed a large number of significant differences that were found in creative and critical thinking scores between the control and the treatment groups, with the treatment groups outperforming the control groups, most frequently within the creative skills tests. In no case did control outperform treatment. With respect to Sub-Hypothesis 1a (divergent thinking, **Table 7**), the treatment group significantly outperformed the control group in 4 of 5 variables measured, with the remaining variable showing no significant difference. With respect to Sub-Hypothesis 1b (convergent thinking, **Table 8**), the treatment group significantly outperformed the control group in 3 of 6 variables measured, with the remaining 3 variables showing no significant difference. With respect to Sub-Hypothesis 1c (critical thinking, **Table 9**), the treatment group significantly outperformed the control group.

These high school findings must be interpreted in the context of **Table 5** above; in some cases, the treatment group's stronger comparative performance resulted in part from a decline in the performance of the control group over the course of the five sessions, as well as from an increase in the performance of the treatment group. In particular, the control group had statistically higher scores on critical thinking and some creative skills on entry to the training than they showed five weeks later. So in **Table 6** through **Table 9** below, while the high school treatment groups outperformed the high school control groups by a statistically significant difference, an important factor contributing to this difference is that in some cases, the high school treatment groups had relatively modest positive changes in critical thinking skills, while the high school control groups had a drop in scores from pretest to post test. While the high school treatment groups do show increases in creative skills during the course of the training, the differences between their group and the high school control group is enhanced by the fact that the high school control group had decreases in their scores, showing higher scores on the entry pre test than the post test. One possible explanation that warrants further study is that a more traditional approach to learning innovation may in some way depress creative thinking, while the arts-based approach may offset that negative impact.

Some of these differences were also found within the early career STEM professionals groups, but to a very slight degree (see **Table 10** through **Table 13** below). There were no statistically significant differences between the early career STEM professionals treatment and control groups, only a slight non-significant trend in Creative Skill 3 (clarity of the problem statement) towards better performance in the treatment group.

Table 6: Summary Table of Differences between Treatment and Control Groups, Hypothesis 1

	High School Students		Early Career STEM Professionals	
Pretest-Posttest Difference Scores	**Significant Group Differences**	**Group with Better Performance**	**Significant Group Differences**	**Group with Better Performance**
Creative Skill 2	Yes	Treatment	No	-
Creative Skill 6	Yes	Treatment	No	-
Creative Skill 7	Yes	Treatment	No	-
Creative Skill 8	Yes	Treatment	No	-
Creative Skill 9	No	-	No	-
Creative Skills 10	Trend	Treatment	No	-
Creative Skills 11	No	-	No	-
Mini-ECCI	Yes	Treatment	No	-
Slover-Linnett Creative Process	No	-	No	-
Basadur's Problem Solving (CPSP)	No	-	No	-
Common Purpose	No	-	No	-
Observed Common Purpose	No	-	No	-
Creative Skills 11	No		No	-

Note: See pages 37-38 above for explanation of Skill 1 through Skill 11.

Table 7: Summary Table of Differences between Treatment and Control Groups, Hypothesis 1a

	High School Students		Early Career STEM Professionals	
Pretest-Posttest Difference Scores	**Significant Group Differences**	**Group with Better Performance**	**Significant Group Differences**	**Group with Better Performance**
Creative Skills 1	No	-	No	-
Creative Skills 2	Yes	Treatment	No	-
Creative Skills 3	Yes	Treatment	Trend	Treatment
Creative Skills 4	Yes	Treatment	No	-
Creative Skills 5	Yes	Treatment	No	-

Note: See pages 37-38 above for explanation of Skill 1 through Skill 11.

Table 8: Summary Table of Differences between Treatment and Control Groups, Hypothesis 1b

	High School Students		Early Career STEM Professionals	
Pretest-Posttest Difference Scores	**Significant Group Differences**	**Group with Better Performance**	**Significant Group Differences**	**Group with Better Performance**
Creative Skills 6	Yes	Treatment	No	-
Creative Skills 7	Yes	Treatment	No	-
Creative Skills 8	Yes	Treatment	No	-
Creative Skills 9	No	-	No	-
Creative Skills 10	Trend	Treatment	No	-
Creative Skills 11	No	-	No	-

Note: See pages 37-38 above for explanation of Skill 1 through Skill 11.

Table 9: Summary Table of Differences between Treatment and Control Groups, Hypothesis 1c

	High School Students		Early Career STEM Professionals	
Pretest-Posttest Difference Scores	**Significant Group Differences**	**Group with Better Performance**	**Significant Group Differences**	**Group with Better Performance**
Critical Thinking	Yes	Treatment	No	-

In the following section, we will go into more specific detail on the results for the described indicators and sub-scales.

Table 10: Table of Divergent Creative Skills Differences, High School Students, Hypothesis 1a

Measurement	Results for High School Students	Averages, Pre to Post	Notes
Change in number of distinct problems identified	The treatment group showed a higher mean number of viable problems (approximately twice as many on average) than the control group, but that difference disappeared once pre-science was controlled for.	Control Pre: 1.7 Control Post: 2.3 Treatment Pre: 1.5 **Treatment Post: 2.9**	Variability in both groups was high. This was due to a number of participants who lost ground from the pretest to the posttest. Twice as many control group high school students lost ground, as did treatment group students.
Change in number of idea clusters the problems represent.	Treatment group had a greater change in the number of idea clusters.	Control Pre: 3.2 Control Post: 2.9 Treatment Pre: 3.0 **Treatment Post: 3.4**	
Change in number of distinct solutions	High school students in treatment group changed more in number of distinct solutions listed.	Control Pre: 3.6 Control Post: 3.4 Treatment Pre: 2.7 **Treatment Post: 3.7**	
Change in number of idea clusters the solutions represent	No significant difference in change between groups.	Control Pre: 2.7 Control Post: 2.7 Treatment Pre: 2.3 Treatment Post: 2.7	The treatment group made more gains. No statistically significant difference is likely because the variability is considerable, and larger in the control group.
Change in number of clusters of reasons for the selection of the solution	Treatment group gained significantly in the number of clusters of reasons offered compared to the control group.	Control Pre: 1.4 Control Post: 0.7 Treatment Pre: 0.7 **Treatment Post: 0.9**	It may be that the significant difference is due to controls losing ground on this measure rather than treatment group members gaining significant ground. This is the first measure in which so many treatment high school students showed strong gains; would be good to investigate this measure to understand why they might have done so.

Table 11: Table of Convergent Creative Skills Differences, High School Students, Hypothesis 1b

Measurement	Results for High School Students	Averages, Pre to Post	Notes
Change in clarity of problem statement	Treatment groups gained more in creating better problem statements.	Control Pre: 1.3 Control Post: 1.6 Treatment Pre: 0.9 **Treatment Post: 1.5**	The confidence interval of the difference between means showed that the difference between the groups was as much as an entire point, which is quite large on a 3- point scale.
Change in strength of solution statement	Treatment group had more gains in providing stronger solution statements compared to the control group.	Control Pre: 1.7 Control Post: 1.8 Treatment Pre: 1.2 Treatment Post: 1.8	The confidence interval of the difference between means showed that the difference between the groups was about one entire point.
Change in number of reasons for the selection of the problem	High school students in the treatment group gained significantly more in number of rationales offered.	Control Pre: 0.7 Control Post: 0.2 Treatment Pre: 0.2 **Treatment Post: 0.4**	Generally speaking, high school students in the control group did not increase their number of rationales given from pre to post.
Change in number of reasons for the selection of the solution.	Treatment group gained more than the control group in the number of rationales for their solutions.	Control Pre: 1.4 Control Post: 0.7 Treatment Pre: 0.7 **Treatment Post: 0.8**	While there was a slight increase in treatment pretest to posttest, the significance resulted from the decrease in the control group.
Change in specificity of what the solution is	No significant difference in change between groups.	Control Pre: 0.9 Control Post: 1.0 Treatment Pre: 0.8 Treatment Post: 1.0	Neither a gain nor a loss on this measure.
Change in specificity of how the solution will be enacted	Treatment group changed more in specificity in how to enact a solution.	Control Pre: 0.2 Control Post: 0.1 Treatment Pre: Less than 0.1 Treatment Post: 0.1	Note that 81% showed neither a gain nor loss on this measure. On average, the control group lost ground, the treatment group gained ground.

Table 12: Table of Divergent Creative Skills Differences, Early Career STEM Professionals, Hypothesis 1a

Measurement	Results for Early Career STEM Professionals	Averages, Pre to Post	Notes
Change in number of distinct problems identified	No significant difference in change between groups.	Control Pre: 2.3 Control Post: 2.6 Treatment Pre: 1.4 Treatment Post: 2.5	While there was no statistically significant difference in the means, the adult treatment group saw a larger gain on this measure pre to post, while more of the control group lost ground from pre to post.
Change in number of idea clusters the problems represent.	No significant difference in change between groups.	Control Pre: 3.8 Control Post: 3.7 Treatment Pre: 3.6 Treatment Post: 3.5	
Change in number of distinct solutions	No significant difference in change between groups.	Control Pre: 3.6 Control Post: 4.2 Treatment Pre: 3.4 Treatment Post: 3.4	
Change in number of idea clusters the solutions represent	No significant difference in change between groups.	Control Pre: 2.6 Control Post: 3.2 Treatment Pre: 2.4 Treatment Post: 2.6	The control group made fractionally more gains from the pretest to the posttest, on average, than did the treatment group. The amount of variability was considerable.
Change in number of clusters of reasons for the selection of the solution	No significant difference in change between groups.	Control Pre: 1.2 Control Post: 1.4 Treatment Pre: 1.2 Treatment Post: 1.1	

Table 13: Table of Convergent Creative Skills Differences, Early Career STEM Professionals, Hypothesis 1b

Measurement	Results for Early Career STEM Professionals	Averages, Pre to Post	Notes
Change in clarity of problem statement	Trend where the treatment group gained more in creating better problem statements.	Control Pre: 1.4 Control Post: 1.5 Treatment Pre: 1.0 Treatment Post: 1.5	This outcome may have hit statistical significance: 1) if the effect had been a little stronger, 2) there were many more participants, or 3) there was less variability in the data.
Change in strength of solution statement	No significant difference in change between groups.	Control Pre: 1.7 Control Post: 1.7 Treatment Pre: 1.6 Treatment Post: 1.7	The difference went in the direction of slightly higher creativity among the treatment adults, compared to control adults, who averaged no gain on this difference measure. However, the difference was not significant.
Change in number of reasons for the selection of the problem	No significant difference in change between groups.	Control Pre: 0.7 Control Post: 0.8 Treatment Pre: 0.6 Treatment Post: 1.0	This measure was divisive for control adults: some gained, others lost.
Change in number of reasons for the selection of the solution.	No significant difference in change between groups.	Control Pre: 1.2 Control Post: 1.4 Treatment Pre: 1.2 Treatment Post: 1.2	
Change in specificity of what the solution is	No significant difference in change between groups.	Control Pre: 1.1 Control Post: 1.0 Treatment Pre: 1.0 Treatment Post: 1.0	High diversity in scores among the adults but the control group showed more losses, over time.
Change in specificity of how the solution will be enacted	A small non-significant difference between the control and treatment adults on this measure.	Control Pre: 0.4 Control Post: 0.3 Treatment Pre: 0.3 Treatment Post: 0.1	On average, both control and treatment groups lost a small bit of ground.

Critical Thinking

We used Basadur and Finkbeiner's (1985) scale on preference for ideation and tendency for premature critical evaluation of ideas. This scale was used in Runco and Basadur's (1993) study on ideation and evaluative thinking change during workplace-based innovation training, and demonstrated a difference between control and treatment groups. Each of these items within the scale was scored in both pre and post surveys, and then the results were used to generate a mean score for both pre and post. The amount of change in mean score for the treatment groups was then compared against the amount of change for the control groups.

For the high school groups, the treatment group made significantly greater pre/post gains than the control group (see **Table 14**). The impact was large; with the treatment group scoring as much as .75 points higher than the control group on some items. The correlation matrix showed that for these cohorts, pre-art and pre-science scores correlated strongly, directly and significantly with each other, $r\ (63) = .52$, $p < .01$. However, the critical thinking difference data did not correlate significantly with pre-art, $r\ (59) = -.14$, $p = .29$, or with pre-science, $r\ (59) = .10$, $p = .43$.

Therefore, high school student differences were examined with an independent samples t-test. There was a significant difference in the direction of greater gains made by the treatment group, with 32 participants, compared to the control group, with 29 participants, $t\ (59) = -2.84$, $p < .01$. The effect of the arts-based learning was large, Glass' Delta = .70. The 95% confidence interval (CI) for the mean differences, -0.69, -0.11, showed that the control group scored as much as three-quarters of a point lower on critical thinking than the treatment group, respectively.

For the early career STEM professionals, there was no significant difference in change between the two groups (see **Table 14**). The correlation matrix showed that none of the correlations were significant (pre-art and pre-science: $r\ (67) = .11$, $p = .39$; pre-science and critical thinking difference: $r\ (67) = -.02$, $p = .88$; pre-art and critical thinking difference: $r\ (67) = .13$, $p = .29$. Therefore, early career STEM professionals group differences were examined with an independent samples t-test. There was no significant difference between the treatment and control group, $t\ (67) = 1.35$, $p = .18$. The difference between the treatment (with 37 participants) and control group (with 32 participants) was as much as half a point but did not reach significance, 95% CI; -0.10, 0.51. Among the treatment group, some adults gained as much as a whole point (maximum = 1.07) whereas some other adults lost nearly a whole point (minimum = 1.00). In sum, this means that both the arts-based and the traditional innovation training had divisive effects on critical thinking for adults, in that some benefited greatly but others lost ground.

Table 14: Critical Thinking Score (Based on Basadur and Finkbeiner)

High School Student Results	High School Student Notes	Early Career STEM Professional Results	Early Career STEM Professional Notes
Significant difference in the direction of greater gains made by the treatment group compared to the control.	The effect was large, showing that the control group scored as much as three-quarters of a point lower than the treatment group.	No significant difference in change between groups.	Among the treatment group, some adults gained as much as a whole point whereas some other adults lost nearly a whole point. Both treatment and control had divisive effects on critical thinking for adults, in that some benefited greatly but others lost ground.

Creative Thinking Skills Self-Report

Creative Competencies Inventory (mini-ECCI)

One of the measures within our pre-post assessments for Creative Thinking was the mini-ECCI. The ECCI stands for Epstein Creativity Competencies Inventory for Individuals, and was developed specifically as an instrument for measurable, trainable competencies. Previous studies (Epstein, Schmidt, & Warfel 2008) have suggested that creative output can be increased through work on strengthening the following four competencies: 1) capturing (preserving new ideas as they occur), 2) challenging (taking on difficult tasks), 3) broadening (seeking knowledge and skills outside one's current areas of expertise), and 4) surrounding (seeking out new stimuli or combinations of stimuli. The version of the ECCI used here was a mini-version, designed for use with individuals, and with fewer items than the original.

For the high school students, the treatment group showed significantly greater gains, when statistically controlling for the effect of pre-science exposure (see **Table 15**). Interestingly, the more Creative Competency gains participants showed from pre to post, the less they reported pre-art or pre-science exposure. Pre-science but not pre-art was a significant covariate. This might imply that high school students with less experience in art or science prior to the workshop are more likely to show short-term measurable impacts from arts-based innovation training.

For the early career STEM professionals, there were no significant differences in change between the control and the treatment groups. Neither pre-art nor pre-science exposure showed significant correlations for the adults.

Overall, creativity, as measured by the ECCI scale, significantly increased in the high school treatment group, and decreased (though not significantly) within the control group (see **Table 16**).

Table 15: ECCI High School Students Pre/Post Change Score Between Groups

	Mean Control	SD	Mean Treatment	SD	Sig?
ECCI Change Score	-0.6	4.8	4.1	9.2	Yes (p<.05)

Table 16: ECCI High School Students Pre/Post Change Score

	Mean Pre	SD	Mean Post	SD	Sig?
Control	59.3	7.1	58.7	6.2	No
Treatment	60.6	7.5	64.7	9.1	Yes (p<.05)

The difference in change scores was not due to the groups beginning at a different starting point, as there was no statistical difference in the pre score for the two groups (see **Table 17**).

Table 17: ECCI High School Students Pre Score Comparison Between Groups

	Mean Control	SD	Mean Treatment	SD	Sig?
ECCI Pre Score	59.3	6.9	60.6	7.5	No

Pre and post scores for the early career STEM professionals had fairly similar means (see **Table 18**). In both the control and the treatment groups, ECCI scores went down in the post assessment, significantly so. The ECCI score fell more in the control group than in the treatment group, and the difference between the pre and the post scores was significant. In comparing the amounts of the decline between control and treatment (see **Table 19**), there were no significant differences in the change scores. While the control group had begun higher than the treatment group, this was not statistically significant (see **Table 20**).

Table 18: ECCI Early STEM Professionals Pre/Post Change Score Within Groups

	Mean Pre	SD	Mean Post	SD	Sig?
Control	63.2	6.2	60.9	6.2	Yes ($p<.05$)
Treatment	61.7	6.1	59.9	5.4	Yes ($p<.05$)

Table 19: ECCI Early STEM Professionals Pre/Post Change Score Comparison Between Groups

	Mean Control	SD	Mean Treatment	SD	Sig?
ECCI Change Score	-2.3	6.1	-1.8	4.2	No

Table 20: ECCI Early STEM Professionals Pre Score Comparison Between Groups

	Mean Control	SD	Mean Treatment	SD	Sig?
ECCI Pre Score	63.2	6.2	61.7	6.1	No

Overall, there was not an increase in the creativity aspects as measured by the ECCI scale in the early career STEM professionals. In fact, there was a statistically significant decrease in creativity in both treatment and control groups.

Creative Problem Solving Profile (CPSP)

Another scale within the pre-post assessment was the Creative Problem Solving Profile (CPSP) developed by Basadur, Graen, and Wakabayashi (1990). The scale measures individual strength within four different components of the creativity process: generation, conceptualization, optimization, and implementation. Each phase has unique attributes. A generator creates options in the form of new possibilities or new problems that might be solved and new opportunities that might be capitalized on. A conceptualizer creates options in the form of alternate ways to understand and define a problem or opportunity, and good ideas that help solve it. An optimizer creates options in the form of ways to get an idea to work in practice and uncovering all of the factors that go into a successful implementation plan. An Implementer creates options in the form of actions that get results and gain acceptance for implementing a change or a new idea. One individual may have a mix of these strengths. Basadur et al. (1990) assert that different individuals have strengths within different phases of the creative process, and that this scale measures their relative strengths. This knowledge can help them improve within areas of the creative process or choose to contribute their efforts to certain phases of creativity that are more productive. They hold that creativity training can improve individuals' strengths within these domains.

When we compare change scores within the high school students (see **Table 21**), there were no significant differences between the treatment and control groups.

Table 21: CPSP High School Students Pre/Post Change Score Comparison Between Groups

Sub-score	Mean Control	SD	Mean Treatment	SD	Sig?
Generation Change Score	-0.8	5.7	-1.2	6.5	No
Conceptualization Change Score	1.3	3.1	1.2	4.5	No
Optimization Change Score	-0.2	3.5	-1.3	3.8	No
Implementation Change Score	0.7	4.7	1.4	4.2	No

Within groups, the control group did experience a statistically significant increase within the conceptualization sub-score (see **Table 22**).

Table 22: CPSP High School Students Pre/Post Change Score, Control Group Only

Sub-score	Mean Pre	SD	Mean Post	SD	Sig?
Generation Change Score	24.8	4.9	24.7	4.8	No
Conceptualization Change Score	19.3	2.9	20.6	3.6	Yes ($p<.05$)
Optimization Change Score	23.6	2.5	23.4	3.9	No
Implementation Change Score	26.1	3.5	26.8	3.8	No

The treatment group had no significantly different scores on the sub-scales (see **Table 23**).

Table 23: CPSP High School Students Pre/Post Change Score, Treatment Group Only

Sub-score	Mean Pre	SD	Mean Post	SD	Sig?
Generation Change Score	27.2	3.6	26.0	5.0	No
Conceptualization Change Score	21.3	3.1	22.5	3.7	No
Optimization Change Score	25.0	3.4	23.7	3.7	No
Implementation Change Score	26.6	3.7	28.0	4.3	No

On this same sub-score where there was an increase in the control, there was also a difference in where the groups began (see **Table 24**). The treatment group began the program significantly higher than the control group in conceptualization.

Table 24: CPSP High School Students Pre Scores Comparison Between Groups

Sub-score	Mean Control	SD	Mean Treatment	SD	Sig?
Generation Change Score	25.0	5.0	27.2	3.6	No
Conceptualization Change Score	19.3	2.9	21.2	3.2	Yes ($p<.05$)
Optimization Change Score	23.9	2.5	25.0	3.3	No
Implementation Change Score	26.1	3.5	26.4	3.7	No

The lack of statistically significant differences among the high school student cohorts when making a direct comparison between control and treatment scores for the four sub-scores on the CPSP means that none of the four sub-scales showed a distinct advantage pre/post for one cohort (control or treatment) over the other. When looking just at the difference scores within each group, the treatment group did not show any significant differences from pre to post for the four subscales. The control group showed one significant difference in the subscales, a significant increase for the conceptualization change score. One factor in this difference was that the control group's mean pretest score was significantly lower a full point than the treatment group, which left more room for the control group to improve. The Creative Problem Solving Profile could be seen as measuring a set of skills that could be very difficult to change in a short period of time given that they represent a person's general approach to the creativity process.

There were no significant differences between change scores of the control and treatment groups for early STEM professionals (see **Table 25**).

Table 25: CPSP Early STEM Professionals Change Score Comparison Between Groups

Sub-score	Mean Control	SD	Mean Treatment	SD	Sig?
Generation Change Score	-1.8	2.8	-1.7	3.1	No
Conceptualization Change Score	-0.2	2.8	-0.6	3.1	No
Optimization Change Score	-0.6	3.5	-1.2	2.6	No
Implementation Change Score	-0.7	2.9	-1.1	3.7	No

The control group did have a slight decline in the Generation sub-score (see **Table 26**), as did the treatment group of early career STEM professionals (see **Table 27**). Early career STEM professionals also experienced a slight decrease in on the optimization sub-scale.

Table 26: CPSP Early STEM Professionals Pre/Post Change Score, Control Group Only

Sub-score	Mean Pre	SD	Mean Post	SD	Sig?
Generation Change Score	27.9	3.7	26.1	3.7	Yes ($p<.01$)
Conceptualization Change Score	20.9	2.6	20.7	2.9	No
Optimization Change Score	24.0	3.3	23.4	2.2	No
Implementation Change Score	26.4	3.9	25.8	3.7	No

Table 27: CPSP Early STEM Professionals Pre/Post Change Score, Treatment Group Only

Sub-score	Mean Pre	SD	Mean Post	SD	Sig?
Generation Change Score	28.1	3.6	26.4	3.8	Yes ($p<.01$)
Conceptualization Change Score	20.9	2.0	20.3	3.0	No
Optimization Change Score	24.3	3.2	23.2	2.4	Yes ($p<.05$)
Implementation Change Score	27.0	3.1	25.9	3.9	No

There were no statistically significant differences in the starting points of each of these groups on the CPSP scales (see **Table 28**).

Table 28: CPSP Early STEM Professionals Pre Scores Comparison Between Groups

Sub-score	Mean Control	SD	Mean Treatment	SD	Sig?
Generation Change Score	27.9	3.7	28.3	3.7	No
Conceptualization Change Score	21.0	2.5	20.9	2.0	No
Optimization Change Score	24.2	3.3	24.3	3.2	No
Implementation Change Score	26.6	4.0	27.0	3.1	No

Transferability of Skills

Increasing individual creative thinking skills and helping learners develop attributes to prepare them for the 21st Century STEM workplace are common goals in many informal STEM learning projects. Nonetheless, the Art of Science Learning project stands out in the project's focus on innovation and to the extent to which it aims to change practice in the home, workplace, and elsewhere. As shown in the comments elsewhere within this report, some individuals took home the lessons and experiences from their innovation training and reported applying them to a wide range of issues. The AVC team wished to measure how well those skills were synthesized and applied elsewhere in participants' lives. Four months after the participants had completed their innovation training, they were asked to fill out a post-workshop survey and reflection, asking the extent to which the lessons they learned during the training could be applied to other contexts, both current and future. The questions were variations of "To what extent have you been able to apply the Innovation Challenge experience to your current work or volunteer activities?" These were post-test items only. Responses were rated on a scale of 1 to 7, with 7 indicating the highest level of transference. A composite transferability of skills score was calculated as an average of the five items listed in **Table 29**.

For the high school students, the treatment group rated the transferability of lessons from the challenge to current and future contexts significantly higher than did the control group. The effect was very large; the actual difference between the two groups' assessments ranged as much as two points. This suggests that those within the treatment group experienced a much greater transference of the skills into their everyday lives.

One item, using a 7-point scale, asked the extent to which the participants would apply their experiences to future work and volunteering: 1 out of 5 (20%) in the control group rated it a 1 "not at all," while not one person (0%) in the treatment group rated it a 1, 2 or 3. Conversely, while 1 out of 5 (21%) in the control group said they were very likely (a 6 or 7) to apply their experiences to future work and volunteering, people in the treatment group were three times more likely (65%) to say they were very likely to do so. Another item using the same scale asked the participants about applying their experiences to school or extracurricular experiences: again, 1 out of 5 (20%) in the control group rated it a 1 "not at all," and again no one in the treatment group rated it a 1, 2 or 3. On the other end of the scale, only one out of three (30%) in the control group rated it a 6 or 7, while twice as many (60%) in the control group thought they would be very likely to apply these experiences to school or extracurricular activities.

It is important to note, however, there were many missing values from the individuals who chose not to fill out the final survey. As approximately half of each of the control and treatment groups did not fill out the survey, it is possible this finding is an artifact of the sample responding. Further work would do well to research this aspect of transferability more thoroughly.

For the early career STEM professionals groups there were no statistically significant differences in the composite score between the control and treatment groups (see **Table 29**). Within the participants there were many missing values, up to half the original sample who completed the five-week workshop. This question should be replicated within any further work in this vein.

Table 29: Transferability of Skills Learning Average Scores

	High School Student Averages	Early Career STEM Professional Averages
To what extent have you been able to apply the experience to your current work or volunteer activities?	Control: 3.7 Treatment: 4.8	Control: 4.1 Treatment: 3.6
To what extent do you think you will be able to apply the experience to your future work or volunteer activities?	Control: 4.1 Treatment: 6.0	Control: 4.5 Treatment: 4.0
To what extent have you been able to apply the experience to your current school or extracurricular activities?	Control: 4.2 Treatment: 5.2	Control: 3.3 Treatment: 3.2
To what extent do you think you will be able to apply the experience to your future school or extracurricular activities?	Control: 4.1 Treatment: 5.8	Control: 4.2 Treatment: 3.6
To what extent have you been able to apply the experience to your current home/personal life?	Control: 3.0 Treatment: 3.7	Control: 3.1 Treatment: 3.2

Definition of Innovation

High School Students

High school student participants were asked to write their definition of innovation as part of the Pre Workshop Survey. Individuals had a wide variety of responses that fell into a few different categories (see **Table 30**). Most often, these participants described innovation as "new ideas" (55%); the next most common definition of innovation involved references to problems and solutions (25%).

Table 30: Definition of Innovation Pre Survey, High School Students

	Control (n=33)	Treatment (n=32)	Total (n=65)
New ideas	58%	53%	55%
Reference to solutions and/or problems	24%	25%	25%
Uniqueness of idea	15%	19%	17%
Process of innovation – brainstorm, reframing, iterating, experiment, collaboration, strategic thinking, etc.	9%	19%	14%
Being creative	12%	12%	12%
Work ethic/ work approach, personal characteristics of the innovator	3%	12%	8%
Product implementation, bringing to market/world, adopter, incremental	0%	3%	1%
Miscellaneous	12%	6%	9%

The most popular definition of innovation given by high school students was as **new ideas**. More than half of the high school students (55%) included this theme as part of their definition.

> *My definition of Innovation is to bring in new ideas.*
>
> *Innovation, in my opinion, is the use of new ideas and solutions for a greater, good purpose.*
>
> *My definition of innovation is creating something new to help others.*

One quarter of students (25%) defined innovation in terms of **solutions and problems**.

> *My definition of innovation would be the process of brainstorming and putting to work ideas and theories.*
>
> *My definition of innovation is having a new, better, and stronger solution to a problem that is put in front of you.*
>
> *For me innovation is experimenting with a specific problem in order to solve it. I see it as a way of making things better for our world, however it doesn't need to only be mechanical, it can be emotional as well.*

Some high school students (17%) wrote about the **uniqueness of an idea** as a definition of innovation.

> *My definition of innovation is a new idea that nobody has ever thought of. An idea that stands*

out from the rest. However, standing out is not the most important element. The most important element is putting an effort into one's work.

Innovation is taking an idea and making it wilder. Taking the old and the new and forming something out of this world. Innovation is being unique, being different, not following the norm but rather strengthening the weird and wacky, its taking the idea's of the insane and finding a solution to a problem with them, inventing a new machine with them and bettering humanity with them.

Some students (14%) used words about the **process of innovation** to define their ideas.

Innovation is development of a concept or idea in order to improve a situation or way of life.

Someone who introduces and communicates a novel way of thinking, interpreting, producing, or solving.

I think that innovation is using new ideas that are usually unrelated to a certain situation to solve a problem that has arisen. I also think it is somewhat of a trial and error process, working things out until they are perfect.

A few students (12%) thought that **being creative** was a definition of innovation.

Innovation is your ability to be original, create new things, like an idea or project. It strongly correlates with creativity.

My definition is when one uses their resources to contract and suggest new and creative ideas or methods.

Innovation is when you can creatively or artistically allow yourself to challenge yourself to create new ideas.

A few students (8%) wrote about the **work ethic and personal character** of an innovator.

My definition of innovation is someone who works hard and is productive and organized.

To me that working hard and bringing clever ideas will lead to an innovator.

A very small number of students (1%) defined innovation in very high-level terms, including **product implementation and bringing product to market.**

Creating new ways and coming up with new ideas and taking them to a whole new level, meaning to put them into good use and good service to the community.

And a few high school students gave responses that did not fit into any of these categories.

Is that innovation is that you start an idea from zero and lead it to become hero.

The next up and coming.

Early Career STEM Professionals

Early career STEM professional participants were also asked to write their definition of innovation as part of the Pre Workshop Survey. Individuals had a wide variety of responses that fell into a few different categories (see **Table 31**). These responses showed a broad similarity to those of the high school student cohorts. Most often, for the early career STEM professionals, participants described innovation as "new ideas" (58%); the next most common definition of innovation involved references to problems and solutions (39%).

Table 31: Definition of Innovation Pre Survey, Early Career STEM Professionals

	Control (n=32)	Treatment (n=37)	Total (n=69)
New ideas	59%	57%	58%
Reference to solutions and/or problems	53%	27%	39%
Process of innovation – brainstorm, reframing, iterating, experiment, collaboration, strategic thinking, etc.	28%	22%	25%
Uniqueness of idea	19%	27%	23%
Being creative	16%	11%	13%
Product implementation, bringing to market/world, adopter, incremental	12%	5%	9%
Work ethic/ work approach, personal characteristics of the innovator	3%	0%	1%
Miscellaneous	3%	8%	6%

The most popular definition of innovation given by adult participants was as **new ideas**. More than half of the adults included this theme as part of their definition.

> *I define innovation as anything new.*
>
> *To invent or begin to apply new methods or ideas*
>
> *A new idea, a new way of doing something.*

Over one third of adults (39%) defined innovation in terms of **solutions and problems**.

> *Innovation is looking at a problem, generating different solutions, and finding an outcome that improves the current state.*
>
> *Developing new approaches or methods to reach solutions.*
>
> *Innovation is taking something you already have or know and applying a new method to solve a problem.*

One quarter of adults (25%) used words about the **process of innovation** to define their ideas.

> *Innovation is the process of brainstorming and developing new or unique solutions to existing issues. The innovation does not necessarily have to be substantial in nature. Even incremental innovation can lead to massive improvements.*

Innovation is ideation that comes to fruition--it is the whole process from defining the problem to brainstorming, to evaluating, to selecting, to executing a successful solution. It is used to solve immediate problems that inhibit work/school/progress.

Innovation is combining creativity and knowledge to develop ideas/products/solutions that have the potential to affect many people in (hopefully) a positive way. Innovation has no limits.

Almost one quarter of adult participants (23%) wrote about the **uniqueness of an idea** as a definition of innovation.

Thinking outside the box to come up with novel solutions or to take from outside disciplines or ideas in order to better solve an issue or problem. You don't need to recreate the wheel, you nearly near to make it better.

Using creative methods for thinking and collaboration to generate new and useful ideas and solutions to daily problems. Often a process that leads to better efficiency in the workplace and within personal spaces as well.

Developing or creating something novel.

Some adults (13%) thought that **being creative** was a definition of innovation.

Using the creative process to develop new ideas or processes.

Innovation is original thought as it relates to creative ways to solve difficult problems. These problems are ones that impact communities, so creative solutions/innovations are necessary when there are so many stakeholders involved.

Thinking of new ways for things to work. Creative problem solving.

A few adult participants (9%) defined innovation in very high-level terms, including **product implementation and bringing product to market.**

When you turn an idea into a product or method that is better than others that already exists.

A new method, idea, or product, put on trial with the hope of success and acceptance of science or art in the eye of the public.

A very small number of adults (1%) wrote about the **work ethic and personal character** of an innovator.

Innovation can take many forms. People who are innovative are not afraid to challenge the norm. They take apart an issue, wrap their heads around it, and then go out into space and look at the problem in its entirety. In a nutshell, I believe the generation of any new way to tackle a problem can be classified as innovation. Innovation can also be the modification of existing knowledge. Coming from an engineering background, I can see any increase in efficiency or production as innovative.

And a few early STEM professionals gave responses that did not fit into any of these categories.

Order out of chaos...

Self Perception as Innovator

This study had many scales on creativity and critical thinking, which the project team hypothesized would increase in individuals once they had had training in innovation. As the training subject matter within both the treatment and the control groups focused on innovation, we asked participants, pre and post, whether they perceived themselves to be innovators at work, school, and home. The question was asked on a 1 to 7 scale, with 1 representing Strongly Disagree and 7 representing Strongly Agree. Within the high school student cohorts, there were no significant differences between control and treatment groups, but there was a slight trend (see **Table 32**). This trend was not due to an increase in the treatment group. Rather, the control group mean showed a mild loss, treatment group did not show a gain or loss. For the early career STEM professionals, there was not much difference between the pretest and posttest scores for either the treatment or control group in innovator self-assessments among adults, but what differences there were, tended to be less in the posttest.

Table 32: Change in Self Perception of Innovation (Innovator Self-Assessment Difference Score)

High School Student Results	High School Student Averages	Early Career STEM Professional Results	Early Career STEM Professional Averages
Trend. There was a non-significant difference in scores between groups.	Control Pre: 5.8 Control Post: 5.1 Treatment Pre: 5.9 Treatment Post: 5.9	Trend. There was a non-significant difference in scores between groups.	Control Pre: 5.4 Control Post: 5.3 Treatment Pre: 5.4 Treatment Post: 5.3

High School Students

Digging further into the perception of innovation, we asked participants in both the pre and the post survey why they had given themselves the ratings they did (see **Table 33**). In addition to talking about new and unique ideas (41%), high school students also cited their ability to be innovators in their personal life (28%) and in their schoolwork and professional work (21%).

Table 33: Self Perception of Innovation Pre Survey, High School Students

	Control (n=33)	Treatment (n=32)	Total (n=65)
New ideas/unique ideas	39%	44%	41%
I am innovative in my personal life/hobbies	33%	22%	28%
My work/school involves/requires innovation	27%	16%	21%
I choose a different path, creative solution, creative output	9%	31%	20%
Reference to solutions and/or problem	3%	16%	9%
My work/school does not allow me to be an innovator	9%	6%	8%
I don't have time at home to be innovative/ I don't want to change things in my personal life	0%	0%	0%
Miscellaneous	21%	12%	17%

High school students most often (41%) referred to **new ideas** when talking about themselves as an innovator.

> *I see myself as an innovator in many regards. I'm always looking for cool new ideas and I always find them in the unlikeliest of places. I'm always looking to improve something, I'm always busy with one thing or another. I tend to start projects before I finish others. I like to do things that have never been done before. Also, I like to "go big or go home".*
>
> *Yes, I see myself as a good sample of an innovator as I try to bring new things everyday.*
>
> *I like to introduce new ideas and new strategies to everything I work with. Whether it's school or work or personal, I love bringing in new concepts.*

More than a quarter of students (28%) felt they were **innovative in their personal life and hobbies**.

> *When it comes to things like schoolwork I like to do it in unconventional ways. Unlike most I don't just sit down and do my homework. I need to be doing something to get myself to better form ideas. When it comes to my hobbies however I am always trying new things and experimenting with different ways. For example when it comes to my beat-boxing I'm always trying to come up with new techniques and sounds to add to my arsenal to make me a better beat-boxer.*
>
> *I sometimes think of easier, simpler ways or doing everyday things. But I rarely come up with things to do with school.*
>
> *I strongly agree that I am an innovator in regards to my personal life because I have had to come up with ways to keep what I hold dear in my busy schedule. I cook almost every day, and I have begun recreating traditionally unhealthy recipes to healthier alternatives. My favorite so far is a cookie cake made with garbanzo beans and maple syrup instead of traditional white flour and sugar. One of my criteria is that it has to taste great, and it always does!*

Over one fifth of the high school students (21%) reported being **innovative in their schoolwork and professional work.**

> *I see myself as a good example of an innovator because I'm always open and enthusiastic about new ideas. During my summer job, I became efficient in the methods they taught me to put case files into the computer and then I created my own method that was more efficient than theirs. I see myself doing this in my life as well. I love taking an idea and improving on it and I see myself doing this in my every day life. If I'm not remembering the material taught in school, I find a more effective way for me to process the information whether this be changing the way I study or the way I learn (a visual vs. verbal learner).*
>
> *I find myself a very innovative and resourceful person. At work, (lifeguarding and restaurant wait staff) I tend to look for solutions to problems and thinking of new ways to do certain tasks until the best solution has been found. I also tend to incorporate similar ideas into my personal life and especially my hobbies (tennis, piano). In school, I try to be as innovative as possible, but I definitely feel restricted due to curriculum requirements.*

In my schoolwork I often find completely different ways of doing assignments, ways that the teacher never thought of when creating the project.

Some students (20%) wrote about being innovative by choosing a **different path or a creative solution** in their life.

Often times I go about a different approach to a problem versus a different approach my peers have chosen.

I believe I am an innovator because I usually take a different approach than others attempting to create more efficient ways of producing a solution.

I see myself as an innovator because I focus on creativity in my life. I follow this because the world would not be unique without differences.

A few student participants (9%) talked about innovation in their life by **defining problems and finding solutions.**

I feel like I am an innovator because I'm always trying to find new solutions for the problems that I face, especially in my personal life and at school. Since I don't have a professional life, my school and my home are the only places where I can try to change, but I'm always looking for new places where I can try to change.

As long as I have a really good feel for what the problem I'm addressing is, and have some sense of the history of trying to solve the problem (previous attempts to solve), I like to think I'm innovative enough to help progress towards a solution, if not solve a problem. In my shop at school, Biotech, we face a lot of problems and are constantly trying to solve them, like making bacteria fluoresce under UV lights and so many other experiments.

I tend to, no matter the situation, try to develop an easier solution that can benefit me and others around me.

Others (8%) felt they **could not be innovative in their school or professional work.**

I don't feel that schoolwork gives me the opportunity to innovate as much as id like. I have a business with my mom and that gives me a lot of artistic innovation. And I am an athlete and musician and I come up with new plays and compose music, which lets me innovate a lot.

My schoolwork is not very "innovatable" to begin with, my work is desk job, and my interests are open enough to create a personal style to go about them.

17% of the participants gave responses that did not fit into any of these categories.

I see myself as an innovator in most challenges I am faced with.

My ratings on whether i am a innovator is that i am organized and try to understand everything

I rated myself that since I believe I am not the best nor the worst innovator and that it depends on the situation at the time.

I kind of wanted to do laser work in the future, like building that kind of stuff in the future.

I don't see myself as an innovator. I prefer to hear other people's ideas and agree or disagree with them. Sometimes with those ideas I would add more on to them.

High School participants were asked to rate and explain their self-perception as an innovator again after completing the Innovation Challenge (see **Table 34**).

Table 34: Self Perception of Innovation Post Survey, High School Students

	Control (n=33)	Treatment (n=32)	Total (n=65)
I am innovative in my personal life/hobbies	39%	47%	43%
I choose a different path, creative solution, creative output	24%	31%	28%
New ideas/unique ideas	33%	16%	25%
My work/school involves/requires innovation	18%	31%	25%
Reference to solutions and/or problem	12%	28%	20%
My work/school does not allow me to be an innovator	18%	16%	17%
I don't have time at home to be innovative/ I don't want to change things in my personal life	0%	3%	1%
Miscellaneous	18%	12%	15%

The high school students most often (43%) said they felt they were innovators in **their personal life and hobbies**.

I gave the ratings I did because I use different techniques to find a solution in school. And, in my personal life, I enjoy drawing, which is creative and innovative.

I do not feel I am much of an innovator when it comes to schoolwork because the assignments are within restrictions. There are some projects where creativity does allot and I can be innovative. On the other hand, I consider myself as an innovator in my personal life because those settings are open ended and I innovate passionately for what I am doing.

At school I always work in a way that defies the norm and really surprises my teachers. In my personal life I am constantly trying out new things in all my hobbies, as well as new hobbies, using trial and error to develop my own way of doing things.

More than a quarter of students (28%) identified as innovators because they chose a **more creative solution or path**.

> *I'm a very creative and imaginative person; I tend to wonder in my mind a lot (when the time is right of course) yet I find that the people around me just know me as a creative person.*

> *I consider myself an innovator because I'm always looking for new things and trying to change what is around me. I like to see things in a different perspective and wonder what would happen if things were different.*

One quarter of high school students (25%) described themselves as innovators because of their **new or unique ideas.**

> *I consider myself to be an innovator because I'm constantly thinking about alternate ideas and ways that can help in everyday life.*

> *I consider my self as an innovator because I always like to take on new challenges and plan or get an original idea out of it.*

> *I like to think of new ideas and methods to do things, and not just follow directions*

One quarter of high school students (25%) believed themselves to be innovators in **their schoolwork, or felt that their schoolwork required innovation**.

> *In schoolwork, I am an innovator because my procrastination is a big problem for me, so I estimate how long a project that I have for a week would actually take me. If in reality, the project takes me two days, I let my self to procrastinate until there are two more days left.*

> *In my school work I almost always go above and beyond to have something new, better, greater, to have the best possible "thing" possible, you see everything you do is a reflection of you so do it the best everyday because putting something off only hurts you. I will take a simple DNA model needed for biology and make a 4 foot tall DNA model chemical and regular that move together; however the parts are commonly used things. In my hobbies as well as in any area of my life I don't follow the rules per say I do everything out of the box, take soccer for example I don't just play conventionally I always see new ways of doing something. I create new ways for things that are seemingly a one-solution problem.*

> *In my schoolwork and personal life I have definitely seen a shift in the way I go about doing something. I'm always looking for different ways to get to a solution and even coming up with newer ways to do things. Some of my coaches and teachers have actually incorporated my ideas into the way they teach something to my team and in class.*

One fifth of students (20%) made reference to **finding solutions to problems** in their lives.

> *I consider myself to be an innovator at my schoolwork and in my personal life because I tend to be a problem solver to no extent, I always try new solutions and new ideas but also I enjoy using old solutions that work, sticking to the basics.*

I take different approaches to solutions than people normally do. And I am confident in my way to communicate.

I spend a lot of time looking for the quickest, most effective way to complete both in and out of school tasks. I create things or put ideas together to solve problems.

Some high school students (17%) felt their **school or work did not allow them to be innovative**.

In school I don't have too many opportunities to be innovative. In my mind I can be creative and express things.

I tend to be less innovative in school because teachers will sometimes set limits that we must conform to in order to succeed, which can be very stifling. In my personal life, i don't limit myself to anything and I am more confident being my own person when i have control over how i can be successful.

A very small number of students (1%) **chose not to be innovative in their personal life, or felt they didn't have the opportunity to be innovative in their personal life.**

In schoolwork, I come up with new solutions and new ways to do the work on my own, I find my own methods and I learn best this way. In my hobbies, such as basketball, I'm working on established plays, not developing my own plays. I value how the coach tells me to do it. But in school, I find there is more flexibility to be innovative and do my own thing.

And a few high school students gave responses that did not fit into any of these categories.

Feel more free to say anything I thought.

I gave this rating because I feel like I am a innovator

In comparing the changes in the high school students' perceptions of themselves as innovators between the pre and posttests, there were broad similarities between control and treatment groups. One notable difference was in the number of participants who mentioned ways in which they were innovative in their own personal and professional lives. The percentage of treatment participants with this response more than doubled (22% pre/47% post) while the control group showed only a very slight increase in this category (33% pre/39% post). Interestingly, the category saying that work or school does not allow them to be an innovator doubled from pre to post for the control participants (9% pre/18% post) and more than doubled for the treatment participants (6% pre/16% post).

Early Career STEM Professionals

Before the start of the Innovation Challenges, each participant was asked to rate him or herself as an innovator, and then asked to explain the rating in his or her own words (see **Table 35**).

Table 35: Self Perception of Innovation Pre Survey, Early Career STEM Professionals

	Control (n=32)	Treatment (n=37)	Total (n=69)
My work/school involves/requires innovation	62%	49%	55%
I am innovative in my personal life/hobbies	28%	38%	33%
I choose a different path, creative solution, creative output	41%	19%	29%
New ideas/unique ideas	22%	35%	29%
My work/school does not allow me to be an innovator	0%	30%	16%
Reference to solutions and/or problem	9%	19%	14%
I don't have time at home to be innovative/ I don't want to change things in my personal life	16%	6%	10%
Miscellaneous	6%	5%	6%

More than half of the early career STEM professionals (55%) reported being **innovative in their schoolwork and professional work.**

> *In my profession, I am responsible for creating and implementing many enjoyable lesson plans and engaging curriculum. I rarely reuse lesson, therefore have to create new activities regularly.*
>
> *I see myself as taking on tasks related to our research and determining the best ways to solve the issue. For example, we worked to develop a calibration scheme to produce accurate and reliable data for atmospheric water measurements.*
>
> *I try to do new things and challenge myself with different and unique projects at school, home, and work.*

One third of adults (33%) felt they were **innovative in their personal life and hobbies**.

> *I don't feel that I'm coming up with new ideas for the classroom, just putting my own spin on things. I do think that I can be more creative in my personal life though. I like to do and try all sorts of new things!*
>
> *I feel much more passionate about my hobbies and personal life versus my professional life and, as such, am more willing to try novel things to keep things interesting and progressive.*
>
> *I'm often told that when I'm interested in something, I really get into it. This often involves creating something out of the ordinary with regard to various hobbies I have.*

Some adult participants (29%) wrote about being innovative by choosing a **different path or a creative solution** in their life.

> *Student: I have a creative edge when it comes to school engineering projects.*

In my professional life I have had to pull together materials and get creative with lesson planning. In my personal life I have had to be creative gathering equipment for different hobbies.

I like to research ideas - whether experiments, Pinterest, art, recipes - then spin off from them to create something new. I also create new things when I research the internet and can't find what I am looking for.

Some adults (29%) referred to **new ideas** when talking about themselves as an innovator.

Always looking for new approaches on old things.

I like to think I am an innovator because I like to come up with new ideas on how to do this and challenge myself to it. I think testing out things that might not always work out is good and can lead to progress.

A few early career STEM professionals (16%) felt they **could not be innovative in their school or professional work.**

At work, I may throw out ideas often, but I am not in a position to put my ideas into motion - it is up to someone else. I am also not often put in a situation where I need to come up with solutions to problems at work. In personal life, I love to come up with new ideas for the hobbies I am interested in.

I don't have much room for flexibility in my job but I do come up with ways to make my job role more efficient and effective.

I don't see myself as a great innovator in my schoolwork because the classes I take all don't require too many different ways to approach the subject. Its very straight forward and I don't try to find a way to think of it differently or even try to relate to another some other subjects.

A few adult participants (14%) talked about innovation in their life by **defining problems and finding solutions.**

I enjoy becoming competent in my fields of interest. I know I'm at a high level when I can provide innovative acceptable solutions to difficult situations.

I see my self as an innovator when brainstorming ideas to solve user experience issues related to technology. I enjoy engaging in design thinking and bouncing ideas off other people. However, I am also a fan of the tried and true solution. If something exists that has previously been done before and works effectively then it should be utilized rather than forcing a new innovation.

A few adults (10%) felt **they did not have time to be innovators in their personal life, or chose not to be innovative in their personal life.**

> *I see myself as creative with my job and finding new ways to teach. In my personal life, I feel like I have my routines and sometimes get stuck in them.*
>
> *In both schoolwork and my professional life (academic) there is a premium placed upon innovation, defined as new ideas to solve problems. In my personal interests, and my personal life, I tend to avoid the adoption of a problem-solving attitude.*

And a few adults (6%) gave responses that did not fit into any of these categories.

> *You can either talk about it...or be about it!*
>
> *I like to be proactive and a foreword thinker.*

After completing the Innovation Challenge participants were again asked to rate and explain their self-perception as an innovator, to see if individuals reported any change in their response (see **Table 36**).

Table 36: Self Perception of Innovation Post Survey, Early Career STEM Professionals

	Control (n=33)	Treatment (n=32)	Total (n=65)
My work/school involves/requires innovation	50%	38%	43%
New ideas/unique ideas	37%	27%	32%
I am innovative in my personal life/hobbies	34%	27%	30%
My work/school does not allow me to be an innovator	22%	22%	22%
I don't have time at home to be innovative/ I don't want to change things in my personal life	22%	16%	19%
I choose a different path, creative solution, creative output	25%	8%	16%
Reference to solutions and/or problem	12%	13%	13%
Miscellaneous	9%	13%	12%

Early career STEM professionals most often (43%) believed themselves to be innovators in **their schoolwork, or felt that their schoolwork required innovation**.

> *I do research in a university lab. Nearly every day I get to come up and test out new ideas - things that have never been done before.*
>
> *At work, I'm a designer. All day I have to creatively and efficiently solve anything from small problems, to large involved problems. Constantly keeping in mind what our competition is doing and researching new technologies and applications. At home, I am always tinkering with my jewelry business or other around-the-house tasks*
>
> *My work requires me to be innovative every day to solve problems that have no solutions.*

Almost one third of adult participants (32%) described themselves as innovators because of their **new or unique ideas.**

> *I always try to think outside of the box. I am constantly thinking of new inventions of new technology and jotting them down in my phone.*
>
> *I consider myself somewhat of an innovator because when I have ideas I like testing them out and don't shoot them down right away.*
>
> *I try out new activities and ideas offered to me in my life, but I also feel that, as a student, I do not have much opportunity to be a major innovator in work or personal life.*

Almost one third of early career STEM professionals (30%) said they were innovative in **their personal life and hobbies**.

> *I don't have much creative freedom at work. With my hobbies, I am able to devote more time to coming up with new ideas.*
>
> *I feel that my hobbies allow for more creative expression (dance and aerial acrobatic performance) and innovation in developing new movements. At work, there are more rules to follow.*

Almost one quarter of adult participants (22%) felt their **school or work did not allow them to be innovative**.

> *At work, it is difficult to be an innovator when so many rules to follow are already in place: for example, under a professor during research or as an EMT, you don't really get to strike out on your own. In my personal life, however, I would consider myself much more of an innovator than average, as I love to explore new areas of science, literature, and outdoor adventures, as these experiences help prevent me from getting bored.*
>
> *I don't do anything meaningful at work.*
>
> *My work lacks interest and recognition for innovation. In my personal life, I know my capabilities for experience.*

Some adults (19%) **chose not to be innovative in their personal life, or felt they didn't have the opportunity to be innovative in their personal life.**

> *I always try to improve my lessons plans and implement new strategies with my students each year. In my personal life, I know what I like and tend to stick with those things.*
>
> *I rated myself fairly high on the innovator scale in my work life because I always try to think of ways to improve processes at work. In my personal life though, I don't think I try to come up with new ideas that often. I try new experiences, but I don't think of ways to improve those experiences.*

Professionally I have supervisors that I must answer to so a lot of my "innovation at work" needs to fall with in parameters that meet their goals/expectations of a program. With that being said, I work in a safe space where new ideas are accepted and supported. I think I have more mainstream/basic hobbies/interests outside of work so I don't think I'm all that innovative in my personal life.

Some adult participants (16%) identified as innovators because they chose a **more creative solution or path**.

I rarely see limits. I am always being told by friends and family that I imagine ideas that others think are brilliant--but never would have thought of.

I consider myself an innovator in my research because I used creative thinking to develop a new method in my field of science. In my personal life/hobbies, I am somewhat of an innovator. I take creative/newish approaches to some of my artsy and athletic hobbies. For example, I created my own exercise hobby that is a mix of belly dancing, tai-chi and balance boarding.

A few adults (13%) made reference to **finding solutions to problems** in their lives.

I see myself to be an innovator because I've been able to step back on my participation in an organization and figure out ways for publicity to be dramatically changed and helped. My ideas build off some other existing ones but it has a twist on it and definitely caters to my demographic and I'm able to see the problem getting them invested.

I feel I am an innovator at work because I do not like to work harder, but smarter so I try to find new ways to work at a problem but differently.

I work as an engineer and often have to come up with a new idea for any given problem. I work with many problems so I have many opportunities to come up with new solutions. At home I love working on art projects and restoration projects that require innovative solutions to problems.

And a few early career STEM professionals gave responses that did not fit into any of these categories.

My biggest struggle with saying I am an innovator is my struggle with the concept of newness.

I live in my head and ides leak out of my body!

I consider an almost graduating innovator because I have yet to produce a product, but I am still learning to.

In comparing the changes in the adult career STEM professionals' perceptions of themselves as innovators between the pre and posttests, there were even more similarities than with the high school students, with no large percentage shifts from pre to the posttests.

As a complement to the question of whether individuals perceived themselves to be innovators, we also asked participants the following question: “Has your perception of yourself as an innovator changed, even a little bit, during your participation in this project?” For those responding affirmatively, we asked the open-end question “in what ways?” to determine the nature of that perceived change.

There were no significant differences between the high school groups to the first question. Both groups ranked their perception of themselves as innovators as changed, with an average of 85% in the control group and 81% in the treatment group. The early career STEM professionals also had no statistically significant differences between groups, though 73% of the adults (87% in the control group and 68% in the treatment group) responded that the course had changed their perceptions of themselves as innovators. See **Table 37** below to see how those students who reported a change in self-perception as innovators characterized that change, with some notable patterns of differentiation.

Table 37: Change in Perception of Self as an Innovator, High School Students

	Control (n=33)	Treatment (n=32)	Total (n=65)
I have improved certain behaviors	61%	78%	69%
Reframing the process of innovation	33%	34%	34%
Collaboration	12%	28%	20%
Divergent thought	12%	19%	15%
Confidence	12%	9%	11%
Finding problem/solution	6%	9%	8%
Leading/following	6%	3%	5%
I have the capacity or interest to be an innovator	9%	6%	8%
Innovation is harder than I thought, it’s challenging, I don’t feel as much like an innovator	15%	0%	7%
My perception has not changed	6%	6%	6%
Miscellaneous	3%	3%	3%

The majority of high school students (69% overall, 61% control/78% treatment) reported **improvement of certain behaviors**, attitudes or skills due to participation in the Innovation Challenge. Breaking down those areas of improvement into more detail:

About one third of high school students (34%) felt their ideas about the process of innovation had been **reframed** and improved.

> *I learned more about innovation in this project, and I learned the process used to properly filter ideas into a solution.*
>
> *It has taught me to focus on the creative side longer.*
>
> *I feel like it improved my way of thinking now I apply it to everything.*

One fifth of students (20% overall, 12% control/28% treatment) said their **collaboration skills** had improved as a result of participating in the program.

> *Before this project I didn't think it was possible that I could work in a group and accomplish a project but now I realize it was just that I’ve just never worked on a project with like-minded*

individuals who actually want to be working on the project.

I never thought innovation could be a collaborative group effort. Normally, I am person who prefers to work alone. This group innovation process has really opened my eyes to how people can collaborate to get something done. This skill is extremely beneficial to my life especially my academic career. I'll definitely bring the skills I acquired from this experience to college next year.

I realized that innovation can happen in a group, rather than just in a person.

Some participants (15%) believed their **ability to think divergently** had improved after taking part in the Innovation Challenge.

I can think of more ideas at once and more angles.

I feel like my ideas are much more coherent than they were before, I think of all the possibilities. For example, before the project I used to walk around having my eyes fixed in just one direction, now I look at all directions and I try to see new things everywhere.

Some participants (11%) felt their **confidence** had improved as a result of participating in the experience.

I feel more confident in my ability to innovate.

I feel much more confident in my abilities of my mind because of the ideas me, along with my team came up with, along with the capacity of my brain to work on multiple problems at once. I feel I am a leader and not a follower and will take action, which I knew these, but they are renewed and given me new found confidence. I believe I have a new process.

A few participants (8%) reported an improvement in **finding problems and solutions**.

I can think more clearly about problems and opportunities to fix them.

I'm more inclined to think about problems in a different way than before.

A few participants (5%) reported an improvement in **leading and/or following**.

I have learnt that I can let others control the situation and that I can sit back and listen to others equally brilliant ideas. I have learnt how to stop panicking about the little things and see the bigger picture and most importantly I have learnt how to communicate with others in order to get my point across and integrate their ideas to the grand scheme of things.

My perception of myself has changed throughout the duration of this project because now I understand how to think of using old things or systems in new exciting ways. Also I think about problem solving and group work differently. I have seen how I have changed and become more of a leader in my group.

Outside of those high school students who said they had improved certain behaviors:

A few participants (8%) felt their self-perception as an innovator changed because they now **felt like they could be an innovator**, compared to their perception before participating in the Innovation Challenge.

> *After participating in this project and learning the specifics of what makes someone an innovator, I can confidently label myself as an innovator.*

> *I actually find that I am even more of an innovator than I thought. I wasn't aware how quick I am at thinking up a plethora of solutions.*

A few participants (7% overall, 15% control/0% treatment) learned that innovation or being an innovator is **more difficult than they originally perceived**.

> *I have realized that I am less of an innovator that I thought I was, or at least that most of my innovations are short-term and relatively easy to implement.*

> *My perception has changed because this project was challenging at times and I realized how hard I actually can work and how much I actually can innovate when I put my mind into it. Before I did things very impetuously, not really thinking things through. Now I know the process for innovation and can systematically work through problems.*

A few high school students (6%) reported that their **perception of themselves as an innovator did not change** as a result of participating in the Innovation Challenge.

> *No, my perception of myself as an innovator did not change during my participation in this project.*

> *My perception didn't really change*

And a few participants gave responses that did not fit into any of these categories.

> *It showed me to see and realize how disorganized Worcester is*

> *I felt as if I was letting the panel really interested into my group's innovation so they would want to see it in the future.*

Early career STEM career participants were also asked in what ways their perception of self as an innovator had changed as a result of participating in the project (see **Table 38**). The majority of early career STEM professional participants mentioned an improvement of certain skills after participating in the Innovation Challenge (54%).

Table 38: Change in Perception of Self as an Innovator, Early Career STEM Professionals

	Control (n=32)	Treatment (n=37)	Total (n=69)
I have improved certain behaviors	59%	49%	54%
Collaboration	19%	24%	22%
Reframing the process of innovation	22%	19%	20%
Confidence	16%	5%	10%
Divergent thought	9%	3%	6%
Leading/following	6%	3%	4%
Finding problem/solution	0%	0%	0%
Innovation is harder than I thought/ I don't feel as much like an innovator	6%	22%	14%
My perception has not changed	12%	16%	14%
I have the capacity/ interest to be an innovator	9%	11%	10%
Miscellaneous	6%	3%	4%

The majority of early career STEM professionals (54% overall, 59% control/49% treatment) reported **improvement of certain behaviors**, attitudes or skills due to participation in the Innovation Challenge. We break down those areas of improvement into more detail below.

Over one fifth of early career STEM professionals (22%) said their **collaboration skills had improved** as a result of participating in the program.

> *This project gave me a deeper understanding of what it looked like to purposefully innovate as a group.*
>
> *I think I have a better understanding of the collaboration process and quantitative steps that are involved.*
>
> *In the past, I experienced generating new ideas in a group setting. The Challenge made it very/more clear that innovation by iteration (off other people's ideas) generates new ideas much faster than working in isolation. This is something I've experienced before, but didn't really recognize the full strength of working in groups in this manner until the Challenge.*

One fifth of adult participants (20%) felt their ideas about the process of innovation had been **reframed** and improved.

> *I really appreciated how thoroughly we went through the innovation process. I recognized the flow of the huge amount of ideas generated during brainstorming, to honing in on a single aspect of a problem, and then developing a multifaceted approach, but I had never really pinned/broken down those separate steps. I bucked at the idea of a structured formula for innovation at first, but then came to accept it as I could see it working in the group.*
>
> *I feel way more open to using different approaches to developing ideas and solutions, especially using more of an artistic approach for what may seem more like a scientific problem - the use of music, doodling, movement, etc.*
>
> *I have learned a lot more about the process of innovation, as well as the way that I respond to it.*

I have learned how to be innovative with a group.

Some participants (10% overall, 16% control, 5% treatment) felt their **confidence** had improved as a result of participating in the experience.

I'm more confident in my thinking, honestly. I had a positive experience during the water challenge and was proud that some of the ideas I had were incorporated into our final project.

Entering the project, I wasn't sure if I'd be able to contribute much to the innovation process since I figured that I'd be one of the youngest members in the project. However, I was excited to see that I could contribute original, innovative ideas based on my own experiences in life, so I've gained more confidence in myself as an innovator.

A few adult participants (6%) believed their **ability to think divergently** had improved after taking part in the Innovation Challenge.

I realize that you don't need to be the smartest person in the room or the loudest to be innovative. Looking at different ideas even if you think they may be crazy at first (the human feces compositing for example) could have potential if there is some ideas to make it mainstream enough to have larger group gain acceptance. It's the balance of ideas that help the wild ideas get closer to usable marketable products.

I suppose I have realized that I can be more creative and come up with more ideas than what I thought I could.

A few participants (4%) reported an improvement in **leading and/or following**.

Mostly learning to share responsibilities and articulation.

Before I didn't believe I was innovative but in the process I felt validated by my team because my leadership skills were able to shine but also my actual engineering skills. Because my team chose the ideas that I helped developed I believe that I am somewhat of an innovator. I also feel like we were able to build off each other's ideas too.

Outside of those early career STEM professionals who said they had improved certain skills or attitudes:

Some adult participants (14%) learned that innovation or being an innovator is **more difficult than they originally perceived**.

I suppose I feel less innovative; I had moments of desiring no innovation when frustrated.

Before the project, innovation was a broader term that included any event that one used their creativity to improve or solve a problem. After the project, innovation equals pressure. The pressure to develop a completely new idea that has the potential to do well in the marketing world. The pressure to develop an idea that is life changing to more than just one person. To me, innovation now seems like something I'm almost incapable of achieving.

It made me feel like I was less of an innovator because it seemed my existing perceptions of the problem at hand kept all my ideas in a box related to how practical they would be in real life.

Some adults (14%) reported that their **perception of themselves as an innovator did not change** as a result of participating in the Innovation Challenge.

It hasn't.

I don't feel I change my way to see things during this project.

I appear to have less patience for poorly thought out ideas.

A few adult participants (10%) felt their self-perception as an innovator changed because they now felt like they could be an innovator, compared to their perception before participating in the Innovation Challenge.

And a few participants gave responses that did not fit into any of these categories.

Using Challenge Skills in the Future

The last question of the transferability instrument focused on the future and participant's ability to implement new skills and knowledge (see **Table 39** and **Table 40**). Participants were asked, "What was the one thing you experienced in the Challenge that you think will be most helpful to you in the future, and why?" The skill most often cited by the high school student cohort was collaboration and teamwork (21%). The skill most often cited by the early career STEM professionals cohort was also collaboration and teamwork (27%).

Table 39: What Will be Most Helpful in the Future, High School Students

	Control (n=33)	Treatment (n=32)	Total (n=65)
Collaboration skills	18%	28%	21%
Process-based innovation skills	15%	25%	20%
Divergent thinking skills	0%	9%	5%
Content knowledge	6%	0%	3%
Miscellaneous	3%	0%	1%

More than one fifth of high school students (21%) said **collaboration skills** would be the most useful thing they learned during the Innovation Challenge.

How to problem solve with groups because it occurs in everyone's daily lives and it is a hard task with so many different opinions and point of views.

Team work skills and never shutting down someone's idea, no matter how strange it is.

Knowing how to work better in a group and effectively communicate. I think this will be most helpful because I tend to shy away from sharing my opinion, but I learned better.

One fifth of high school participants (20%) felt the **process-based innovation skills** would be the most useful thing they would take away from the Challenge.

> *Learning about how innovation is a process, will help me follow along that process when the time comes for projects and such.*

> *The funneling of possible solutions to an exact solution.*

> *Brainstorming ideas and idea development because it important to try new things.*

A few students (5%) mentioned **divergent thinking** as a skill they learned during the Innovation Challenge that would be helpful to them in the future.

> *I think thinking from a different perspective because it opens up a whole new world of ideas.*

A few students (1%) gained **content knowledge** during the Innovation Challenge that would be helpful to them in the future.

> *How travel can be improved.*

And a few high school students gave responses that did not it into any of these categories.

> *That when forced to work with idiots, nothing gets done.*

Table 40: What Will be Most Helpful in the Future, Early Career STEM Professionals

	Control (n=32)	Treatment (n=37)	Total (n=69)
Collaboration skills	28%	27%	27%
Process-based innovation skills	28%	16%	22%
Content knowledge	9%	11%	10%
Divergent thinking skills	0%	0%	0%

Note: Visitors could provide more than one response to this item so the column percentages total more than 100%

More than one quarter of early career STEM professionals (27%) said **collaboration skills** would be the most useful thing they learned during the Innovation Challenge (see **Table 40**).

> *Unifying thoughts and team members from varying backgrounds around a technical solution for a problem that deeply affects all individuals living in Southern California.*

> *Collaboration in an interdisciplinary team.*

> *Being able to work with a group and get the task done under pressure.*

More than one fifth of adult participants (22%) felt the **process-based innovation skills** would be the most useful thing they would take away from the challenge.

> *Writing the business plan- I have a small side business that I'm working on growing, so I'll need to.*
>
> *The idea to iterate, design, iterate, and design again.*
>
> *Brainstorming activities.*

Some adults (10%) gained **content knowledge** during the Innovation Challenge that would be helpful to them in the future.

> *I learned that water is a public good, not a commodity. I think that was very essential to approach the water problem that I didn't know until Week 3. That led me to think about energy, which is a commodity, not a public good, and how that changes the economic environment between the two different entities. Outside of the technical background, this enlightened me to look into other aspects that can be very critical to making new services/products successful.*
>
> *I have a better understanding of watersheds and how to help preserve them.*
>
> *Knowledge of how the water system works.*

Unlike the high school students, no early career STEM professionals mentioned divergent thinking as a skill they learned during the Innovation Challenge that would be helpful to them in the future.

Hypothesis 2 Findings: Collaboration Behaviors

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

Collaboration plays a central role in virtually all innovation processes, which is reflected in the team-based nature of the Art of Science Learning innovation curriculum. Hypothesis 2 took a closer look at the impact of arts-based learning on the collaborative behaviors of innovation teams faced with increasingly complex and demanding collaborative tasks over a five-week period. Collaboration was researched by observing eleven collaborative behaviors within the teams, as well as by asking teams to reflect on how well they worked together, with overlap between items that formed the basis for observational and participant reports.

For the observed behaviors, data collectors observed teams when they were working together in any capacity, such as activities, brainstorming, or on their problems and solutions. As participants were wearing name tags, data collectors specifically recorded which of the individuals they saw engaging in each of the eleven behaviors during a given observation period, which usually was between 10 and 30 minutes. If any activity lasted longer than 30 minutes, halfway through observers would switch to another team so to better balance the amount of collaborative activity that was observed among the various teams. The total number of individuals who engaged in the behaviors was then totaled for each team per each observed block of activity; these blocks were then added together to produce data on total number of observed instances of each activity for each of the teams that day. This last number is what is represented in the analyses below.

For the self-reported team rating measures included in this section, each individual filled out a short survey at the end of each week that included ratings for the same collaborative behaviors being observed. For the self-report team rating measures, individuals rated their team (as opposed to particular individuals on their team) on each of the eleven items. In this manner, the observations and surveys were intended to provide multiple ways to measure the same variables and a comparison could be made between what the researchers observed and what the team members perceived. Appendices C and D include the observational and self-reported team collaboration rating measures, respectively.

Observed Collaboration

In order to determine whether or not there was a change in specific collaborative behaviors, an analysis was run to determine whether each individual showed that collaborative behavior more, less or the same at the end of the research period as they did at the beginning. Then, the percentage breakdown of the three categories was compared for the treatment and control groups independently. In other words, the analysis told whether there was a difference for either cohort from the beginning to the end of their participation. For the high school students there were significant increases in positive collaborative behaviors in both the control (6 of 11 measures) and treatment (5 of 11 measures) conditions (see **Table 41).** When looking at the early career STEM professionals, it was more one-sided: the control condition showed a significant increase for only 1 of the 11 positive collaborative behaviors, while the treatment condition showed a significant increase for 7 of the 11.

Table 41: Summary Table of Observed Collaboration and Other Innovation Processes Differences (Pre/Post Observational Difference Scores)

	High School Students		Early Career STEM Professionals	
Observational Category	**Statistically Significant Group Differences?**	**Group with Better Performance (Pre/Post)**	**Statistically Significant Group Differences?**	**Group with Better Performance (Pre/Post)**
Shares leadership	Yes	Control	Yes	Treatment
Active follower	No	-	Yes	Treatment
Emotionally intelligent behavior	Yes	Treatment	Yes	Treatment
Empathic listening	Yes	Treatment	Yes	Treatment
Mutual respect	No	-	Yes	Treatment, Control
Trust in moving toward solution	Yes	Treatment, Control	Yes	Treatment
Transparent in communication	Yes	Control	Yes	Treatment
Ability to disagree productively	Yes	Treatment	No	-
Defining a common purpose	Yes	Control	No	-
Creating culture of mutual accountability	Yes	Control	No	-
Productively manages disruption	Yes	Treatment, Control	No	-

Self-Reported Collaboration

For the self-reported team collaboration rating measures, individuals rated themselves on fifteen collaborative behaviors; this was done during a pre-test in the first session, and during a post-test in the last session. A difference score was calculated by subtracting the pre-test rating or score on an item from the post-test score on that same item. If one or both of the items was missing, then that individual was not included in the comparison. Two statistically significant differences emerged for the high school students; the control group was more likely to report a positive change from pre-test to post-test in mutual respect and also trust (see **Table 42**). In looking at the early career STEM professionals there were no statistically significant differences in the pre-test post-test change scores. This means that the adults did not perceive any notable differences from the beginning of participation to the end in the various collaboration scores, either those in the control or treatment conditions.

Table 42: Summary Table of Self-Reported Team collaboration Ratings and Other Innovation Processes Differences (Pre/Post Self-Reported Difference Scores)

	High School Students		Early Career STEM Professionals	
Self-Report Category	**Statistically Significant Group Differences?**	**Group with Better Performance (Pre/Post)**	**Statistically Significant Group Differences?**	**Group with Better Performance (Pre/Post)**
Shares leadership	No	-	No	-
Active follower	No	-	No	-
Emotionally intelligent behavior	No	-	No	-
Empathic listening	No	-	No	-
Mutual respect	Yes	Control	No	-
Trust in moving toward solution	Yes	Control	No	-
Transparent in communication	No	-	No	-
Ability to disagree productively	No	-	No	-
Defining a common purpose	No	-	No	-
Creating a culture of mutual accountability	No	-	No	-
Productively manages disruption	No	-	No	-
Successfully completed task	No	-	No	-

Relationship Between Observed and Self-Reported Collaboration

It is interesting that the observed collaboration measures showed a much larger impact than the self-reported team collaboration rating measures. Although neither control nor treatment groups rated themselves as having improved on any of the self-reported team rating measures, observers recorded the treatment groups as having engaged in many of these behaviors significantly more by the last session. The difference was particularly evident among the early career STEM professionals, but the high school students also showed a much higher rate of significance for observed collaborative behaviors compared to their self-reported team rating behaviors. These findings suggest that simply asking people about their collaborative behaviors may not be enough to accurately portray the nature and extent of collaboration occurring during group tasks; and that third party observation is important to understanding the occurrence of these behaviors.

High School Student Observed Behavior Findings

The tables in the first part of this section **(Table 43** through **Table 53)** show the observed behavior ratings by the researchers from R2 (week 2) through R5 (week 5) and include total behaviors per team per session; see Appendix C for the individual behaviors studied. A table is included for each of the eleven behaviors observed by the researcher, breaking down the number of times this particular behavior was observed for each team during each week. The overall sum of behaviors observed in each week is included at the bottom of the table.

Note: R1 (week 1) observational data were collected for the treatment group, but not for the control group. Since the observational data for high school students in R1 are incomplete, R1 has been excluded from the tables and figures below, as well as all related statistical analyses.

In order to compare the groups on each behavior, statistical tests were run on the differences between the frequency and patterns of occurrence these behaviors were observed in control and treatment over the R2 to R5 period. If there was a statistically significant difference between the control and treatment groups, a line graph was included below the table. Tables without accompanying line graphs showed no statistically significant differences between control and treatment.

Based on the R2 to R5 totals, behaviors most commonly observed were being an active follower (see **Table 44)** and empathic listening (see **Table 46**). These were followed by emotionally intelligent behaviors (see **Table 45**) and being transparent in communications (see **Table 49**). The next highest totals were for the ability to disagree productively (see **Table 50**), being mutually respectful (see **Table 47**), creating a culture of mutual accountability (see **Table 52**), and moving towards a solution (see **Table 48**).

As mentioned above, there was a comparison of treatment and control groups in the frequency and pattern of the eleven behaviors from R2 through R5. Cross-tabulations were run looking at the percentage of individuals in the control and treatment groups engaging in each specific behavior, across weeks 2 through 5. This type of analysis was chosen since it allowed a direct comparison between the two groups, to see whether or not being in one group increased or decreased the likelihood of engaging in that particular behavior. The eight that showed a statistically significant difference include behaviors related to sharing leadership, trust in moving towards a solution, being transparent in communication, emotionally intelligent behavior, the ability to disagree productively, defining a common purpose, creating a culture of mutual accountability, and productively managing disruption.

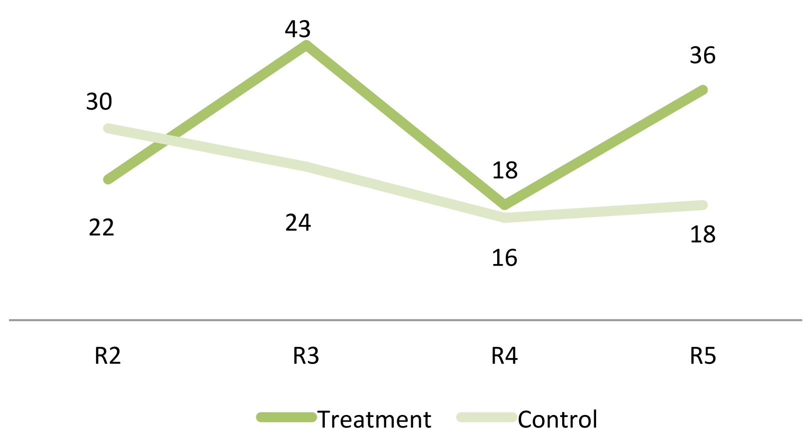
Comparison Between Control and Treatment by Behavior

Shares Leadership
The occurrence of the behavior was highest in R3, followed by R2 and R5, then R4. There was a statistically significant difference in the frequency and pattern of these behaviors over time in comparing control and treatment groups. While the control group had more occurrences this behavior in R2 compared to the treatment group, and they were roughly even in R4, the treatment group had roughly twice as many occurrences in R3 and R5, compared to the control group.

Table 43: Sum of Shares Leadership Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	6	10	3	11
2 (treatment)	10	15	6	6
3 (treatment)	3	8	5	9
4 (treatment)	3	10	4	10
5 (control)	10	7	5	8
6 (control)	10	7	6	2
7 (control)	8	1	3	6
8 (control)	2	9	2	2
Overall sum	**52**	**67**	**34**	**54**

Figure 2: Shares Leadership, Sum of Observed Behaviors in Groups Over Time, High School Students



Active follower

The behavior of active following was one of the more common behaviors recorded, with totals of over 200 instances observed for each week from R2 through R5; the highest frequencies were in R2 and R4. There was not a statistically significant difference in the frequency and pattern of these behaviors over time in comparing control and treatment groups.

Table 44: Sum of Active Follower Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	19	26	37	31
2 (treatment)	32	31	24	40
3 (treatment)	32	33	31	29
4 (treatment)	32	28	26	35
5 (control)	48	34	35	36
6 (control)	39	27	27	33
7 (control)	36	28	25	34
8 (control)	45	24	20	35
Overall sum	**283**	**231**	**225**	**273**

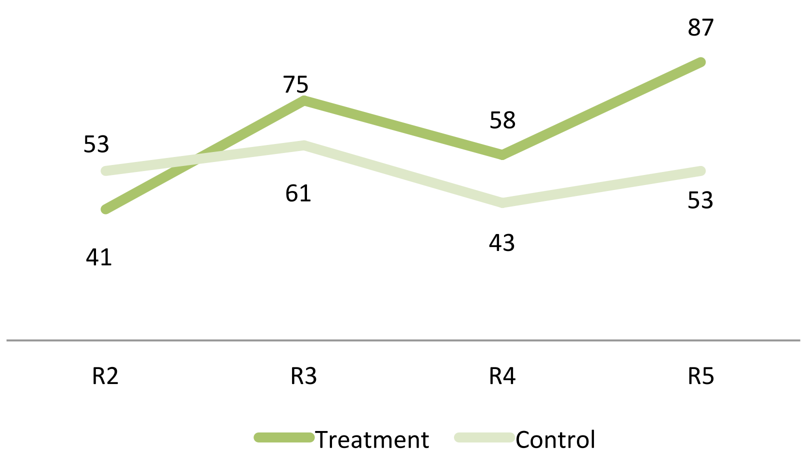
Emotionally intelligent behavior

There were a higher number of occurrences in R3 and R5, compared to R2 and R4. There was a statistically significant difference for the frequency and pattern of emotionally intelligent behavior observed in comparing the control and treatment groups. While the control group had a slightly higher number of occurrences in R2, the treatment group had a higher number than the control group for R3, R4 and R5.

Table 45: Sum of Emotionally Intelligent Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	10	20	16	22
2 (treatment)	13	26	14	19
3 (treatment)	10	12	16	23
4 (treatment)	8	17	12	23
5 (control)	16	22	20	20
6 (control)	16	13	11	17
7 (control)	8	14	7	9
8 (control)	13	12	5	7
Overall sum	**94**	**136**	**101**	**140**

Figure 3: Emotionally Intelligent Behavior, Sum of Observed Behaviors in Groups Over Time, High School Students



Empathic listening

From R2 through R5 there was a steady increase in empathic listening across all four sessions. There was not a statistically significant difference in the frequency and pattern of these behaviors over time in comparing control and treatment groups.

Table 46: Sum of Empathic Listening Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	12	23	35	30
2 (treatment)	13	26	24	32
3 (treatment)	23	20	24	33
4 (treatment)	14	25	25	32
5 (control)	35	24	31	37
6 (control)	26	21	27	31
7 (control)	23	21	23	29
8 (control)	31	22	18	26
Overall sum	**177**	**182**	**207**	**250**

Mutual respect

The total instances of mutual respect observed were similar across all eight teams in R2 and R3, dipped in R4 and then shot up substantially in R5. There was not a statistically significant difference in the frequency and pattern of these behaviors over time in comparing control and treatment groups.

Table 47: Sum of Mutual Respect Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	5	11	0	19
2 (treatment)	6	14	7	17
3 (treatment)	18	8	9	17
4 (treatment)	3	11	0	17
5 (control)	9	6	3	12
6 (control)	6	4	1	17
7 (control)	7	4	0	12
8 (control)	7	7	3	6
Overall sum	**61**	**65**	**23**	**117**

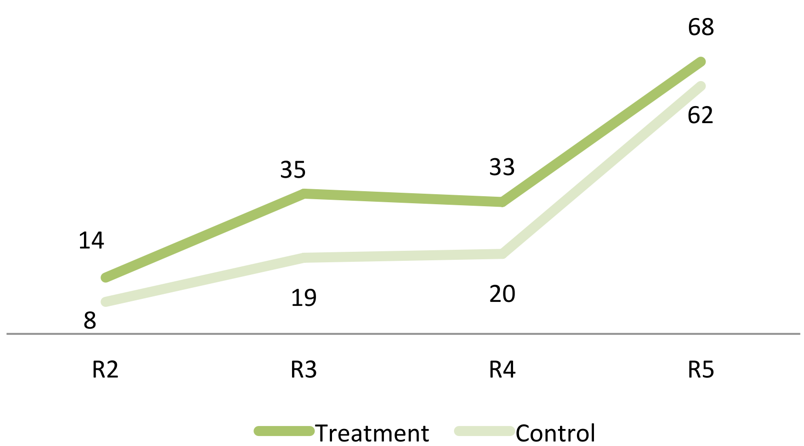
Trust in moving toward solution

The behaviors observed for trust in moving toward a solution increased substantially from R2 to R5. There was a statistically significant difference in the frequency and pattern of these behaviors between control and treatment groups. The treatment group showed a higher number of these behaviors each of the four weeks, with the largest differences being in R3 and R4.

Table 48: Sum of Trust in Moving Toward Solution Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	0	14	5	21
2 (treatment)	4	10	10	17
3 (treatment)	4	11	12	16
4 (treatment)	0	0	6	14
5 (control)	6	7	8	22
6 (control)	0	6	4	18
7 (control)	6	3	4	9
8 (control)	2	3	4	13
Overall sum	**22**	**54**	**53**	**130**

Figure 4: Trust in Moving Toward Solution, Sum of Observed Behaviors in Groups Over Time, High School Students

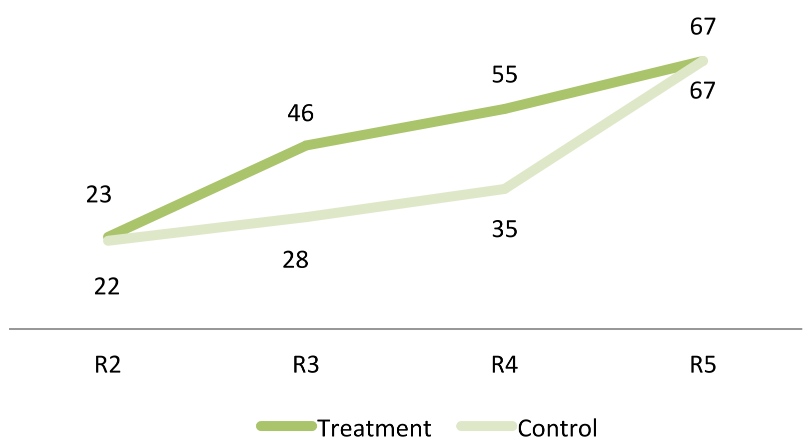


Transparent in communication
For this behavior, there was a steady increase from R2 through R5~~.~~ There was a statistically significant difference between control and treatment groups in the frequency and pattern of these behaviors. The numbers for each group were almost identical for R2 and R5, while the treatment group had more occurrences in R3 and R4.

Table 49: Sum of Transparent in Communication Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	4	13	11	14
2 (treatment)	9	16	16	17
3 (treatment)	6	7	15	20
4 (treatment)	4	10	13	16
5 (control)	7	8	12	18
6 (control)	1	8	10	15
7 (control)	9	5	6	16
8 (control)	5	7	7	18
Overall sum	**45**	**74**	**90**	**134**

Figure 5: Transparent in Communication, Sum of Observed Behaviors in Groups Over Time, High School Students



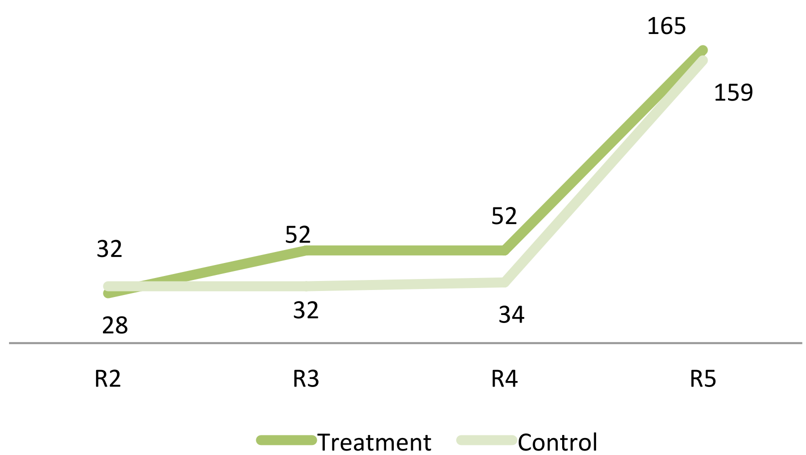
Ability to disagree productively

Participants' ability to disagree productively evolved in somewhat of a bell curve, with the larger number of occurrences in R3 and R4, and fewer in R2 and R5. There was a statistically significant difference between control and treatment groups in the frequency and pattern of these behaviors, with the treatment group having more occurrences compared to the control group in three of the four sessions. Since we only observed productive disagreement, it is not possible to infer whether there was a difference in non-productive disagreement.

Table 50: Sum of Ability to Disagree Productively Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	3	15	9	8
2 (treatment)	11	20	10	9
3 (treatment)	6	3	16	10
4 (treatment)	8	14	17	6
5 (control)	14	15	16	3
6 (control)	7	8	9	4
7 (control)	6	0	4	5
8 (control)	6	9	5	5
Overall sum	**61**	**84**	**86**	**50**

Figure 6: Ability to Disagree Productively, Sum of Observed Behaviors in Groups Over Time, High School Students



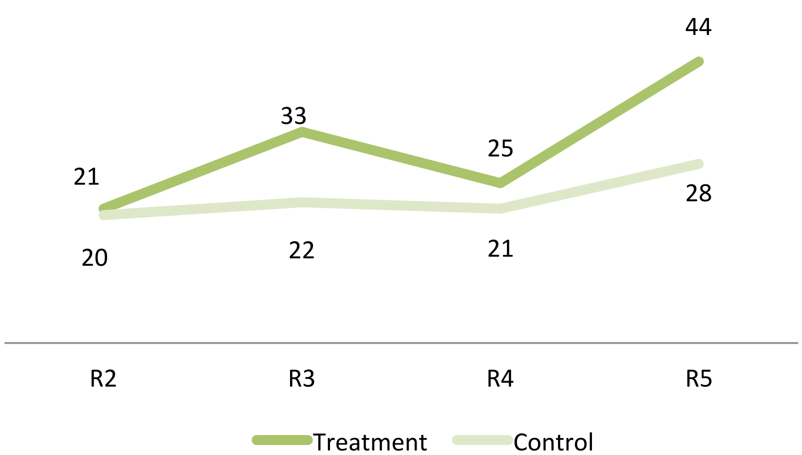
Defining a common purpose

The highest level of occurrence was in R5, followed by R3, R4 and R2. There was statistically significant difference in the frequency and pattern of this behavior between control and treatment groups. While occurrences were relatively similar in R2 and R4, there was a much higher occurrence of this behavior for the treatment group in R3 and R5.

Table 51: Sum of Defining a Common Purpose Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	2	10	7	15
2 (treatment)	10	8	6	9
3 (treatment)	8	10	9	10
4 (treatment)	1	5	3	10
5 (control)	7	7	3	10
6 (control)	7	8	5	5
7 (control)	6	1	8	9
8 (control)	0	6	5	4
Overall sum	**41**	**55**	**46**	**72**

Figure 7: Defining a Common Purpose, Sum of Observed Behaviors in Groups Over Time, High School Students



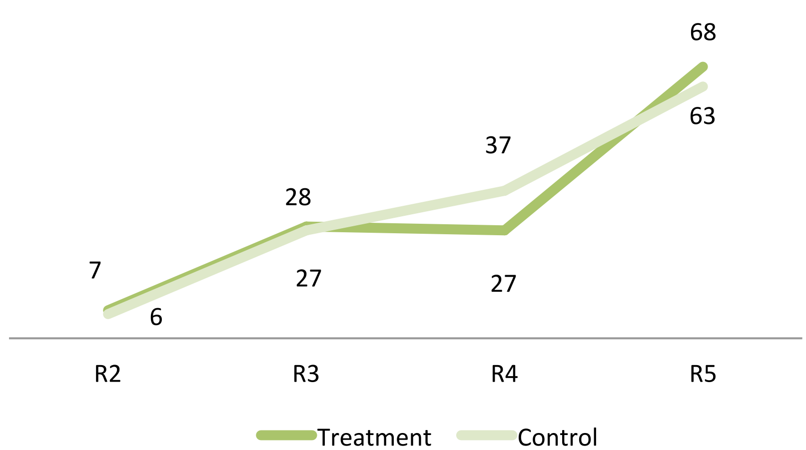
Creating culture of mutual accountability

The behavior of creating a culture of mutual accountability had one of the largest increases from R2 to R5. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups. This difference, however, was driven by a single week (R4) where the control group had a higher degree of this behavior compared to the treatment group. The treatment group had a higher degree of this behavior compared to the control group in R2, R3 and R5.

Table 52: Sum of Creating Culture of Mutual Accountability Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	0	6	12	25
2 (treatment)	0	9	0	16
3 (treatment)	7	9	11	16
4 (treatment)	0	4	4	11
5 (control)	4	10	22	19
6 (control)	1	6	7	22
7 (control)	1	3	5	8
8 (control)	0	8	3	14
Overall sum	**13**	**55**	**64**	**131**

Figure 8: Creating a Culture of Mutual Accountability, Sum of Observed Behaviors in Groups Over Time, High School Students

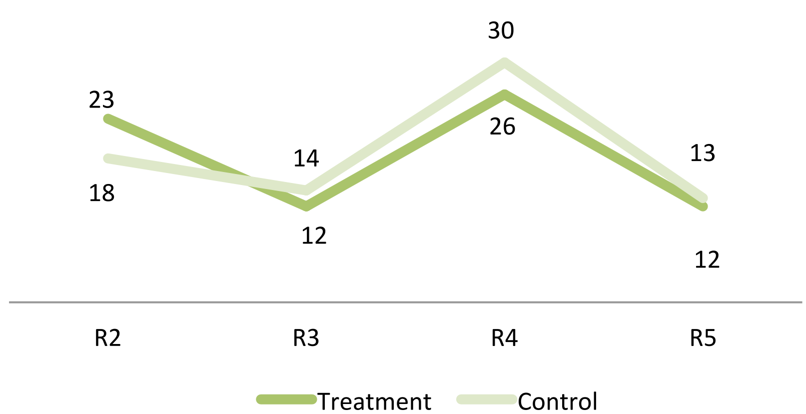


Productively manages disruption
The highest number of occurrences was observed in R2 and R4, with lower numbers for R3 and R5. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups, the with control group showing the stronger performance. The treatment group had a higher number of occurrences in R2, due to a large number of occurrences in one particular treatment team, while the control group had a higher number of occurrences in R3 to R5.

Table 53: Sum of Productively Manages Disruption Behaviors Observed, High School Students

Team	R2	R3	R4	R5
1 (treatment)	0	1	7	3
2 (treatment)	13	6	3	6
3 (treatment)	5	4	9	1
4 (treatment)	5	1	7	2
5 (control)	5	5	10	8
6 (control)	3	5	9	4
7 (control)	8	2	6	0
8 (control)	2	2	5	1
Overall sum	**41**	**26**	**56**	**25**

Figure 9: Productively Manages Disruption, Sum of Observed Behaviors in Groups Over Time, High School Students



Comparison Between Control and Treatment in the Final Session

Looking at teams' observed behaviors over the course of the project allowed for an understanding of how the teams progressed during the weekly sessions. The final session, R5 represents the culmination of the project's innovation training, and looking specifically at the R5 outcomes gives us the ability to study the ways in which the collaborative behaviors of the control and treatment groups were impacted by the 20 hours of training.

In order to compare the comparative impacts of full the full 20-hour intervention, a statistical test was run, looking at the difference in the frequency of each of the eleven behaviors in R5, between the control and treatment groups.

Of the eleven comparisons, the following table shows five behaviors with statistically significant differences: shares leadership, emotionally intelligent behaviors, mutual respect, ability to disagree productively, and defining a common purpose (see **Table 54**). All of these showed a higher level of occurrence for the treatment group. Both control and treatment teams spent R5 finalizing their final presentations and business cases related to the challenge, so there were a lot of opportunities for collaborative behaviors. The treatment group engaged in these types of behaviors significantly more than the treatment group, suggesting that the treatment group was acting more collaboratively as they figured out the final pieces and details of their presentations.

Table 54: Summary Table of Observed Collaboration and Other Innovation Processes Differences, Only for Week 5 (R5) (Pre/Post Observational Difference Scores)

	High School Students	
Observational Category	**Statistically Significant Group Differences?**	**Group with Better Performance (Pre/Post)**
Shares leadership	Yes	Treatment
Active follower	No	-
Emotionally intelligent behavior	Yes	Treatment
Empathic listening	No	-
Mutual respect	Yes	Treatment
Trust in moving toward solution	No	-
Transparent in communication	No	-
Ability to disagree productively	Yes	Treatment
Defining a common purpose	Yes	Treatment
Creating culture of mutual accountability	No	-
Productively manages disruption	No	-

Self-Reported Team Collaboration Ratings of High School Students

The tables in this section are the individual self-reported team ratings of the high school participants of their own behaviors during each session (see **Table 55** through **Table 65**). While the observed behaviors did not include R1, each participant filled out the survey at the end of each session, including R1. Therefore, comparisons for self-reported sessions are made between R1 and R5.

All of the measures saw an increase in the average rating from R1 to R5. The three biggest increases were an increase of 1.3 for active following (see **Table 56**), 1.1 for empathic listening (see **Table 58**), and 1.0 for ability to dispute productively (see **Table 62**). The highest ratings in the last week (R5) included shares leadership (see **Table 55**) and being an active follower (see **Table 56**), followed by mutual respect (see **Table 59**), and the ability to disagree productively (see **Table 62**). Next were empathic listening (see **Table 58**), trust in moving towards a solution (see **Table 60**), defining a common purpose (see **Table 63**), and creating a culture of mutual accountability (see **Table 64**). R5 average scores ranged from 6.0 to 6.8. No significant differences in R1/R5 change were seen between control and treatment groups.

Table 55: Shares Leadership Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.5	6.0	5.8	6.8	7.0
2 (treatment)	6.1	6.1	6.3	6.6	6.8
3 (treatment)	6.3	6.1	6.4	5.2	6.0
4 (treatment)	5.1	6.3	6.1	6.5	6.6
5 (control)	3.9	6.0	5.8	4.4	6.2
6 (control)	5.2	6.3	6.6	6.3	6.7
7 (control)	4.7	5.3	5.9	6.1	6.1
8 (control)	5.6	6.8	6.7	6.6	6.6
Overall average	**5.3**	**6.1**	**6.2**	**6.1**	**6.5**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 56: Active Follower Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.3	6.1	6.0	6.9	6.6
2 (treatment)	6.5	5.5	5.4	6.5	6.6
3 (treatment)	6.3	6.0	6.6	5.2	6.1
4 (treatment)	3.8	6.4	6.0	6.5	6.5
5 (control)	3.4	5.9	5.8	4.4	6.1
6 (control)	5.4	6.3	6.3	6.5	6.8
7 (control)	5.3	5.1	6.4	5.9	6.2
8 (control)	5.8	6.6	6.6	6.7	6.8
Overall average	**5.2**	**6.0**	**6.1**	**6.0**	**6.5**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 57: Emotionally Intelligent Behavior Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.0	5.9	4.8	6.6	6.5
2 (treatment)	6.1	5.4	6.8	6.3	6.5
3 (treatment)	6.1	6.3	6.1	5.2	4.6
4 (treatment)	5.1	6.0	5.0	6.3	6.3
5 (control)	5.2	5.8	5.8	3.8	6.2
6 (control)	5.3	6.2	6.1	6.0	6.7
7 (control)	5.0	4.9	6.4	6.1	6.3
8 (control)	4.9	6.6	6.7	6.6	6.6
Overall average	**5.3**	**5.9**	**6.0**	**5.8**	**6.2**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 58: Empathic Listening Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	4.9	5.1	4.1	6.7	6.9
2 (treatment)	6.3	5.6	6.1	6.6	6.8
3 (treatment)	6.2	6.3	6.5	6.2	5.3
4 (treatment)	5.0	6.1	5.4	6.3	5.8
5 (control)	3.6	5.7	6.0	3.8	6.1
6 (control)	5.6	6.2	6.1	6.2	6.3
7 (control)	5.2	5.4	6.6	6.3	6.3
8 (control)	5.3	6.7	6.6	6.6	6.5
Overall average	**5.2**	**5.9**	**5.9**	**6.1**	**6.3**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 59: Mutual Respect Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.9	5.1	4.4	6.7	6.9
2 (treatment)	6.9	6.5	4.8	6.4	6.1
3 (treatment)	6.4	6.9	6.5	5.2	6.2
4 (treatment)	5.6	6.2	6.0	6.4	6.0
5 (control)	4.8	5.3	5.4	4.4	6.8
6 (control)	5.5	6.6	6.2	6.6	6.4
7 (control)	5.8	5.6	6.4	6.0	6.3
8 (control)	4.7	6.9	6.7	5.9	6.8
Overall average	**5.7**	**6.2**	**5.8**	**5.9**	**6.4**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 60: Trust in Moving Toward Solution Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.7	5.4	4.4	6.8	6.5
2 (treatment)	6.1	5.8	6.8	6.5	6.6
3 (treatment)	6.9	6.0	6.4	5.6	5.4
4 (treatment)	5.4	5.4	6.0	6.5	6.1
5 (control)	3.7	5.9	5.1	4.3	6.7
6 (control)	5.3	6.5	6.6	6.6	6.4
7 (control)	5.4	5.1	5.8	6.4	6.2
8 (control)	5.6	6.8	6.7	6.8	6.4
Overall average	**5.5**	**5.9**	**6.0**	**6.1**	**6.3**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 61: Transparent in Communication Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.1	5.3	4.8	6.4	6.8
2 (treatment)	6.4	6.8	5.7	6.3	6.7
3 (treatment)	6.1	6.1	6.4	5.1	5.6
4 (treatment)	4.8	6.4	6.0	6.1	6.1
5 (control)	5.3	5.6	6.0	4.9	5.4
6 (control)	5.4	5.9	6.3	6.0	6.0
7 (control)	5.3	5.3	5.7	6.1	6.1
8 (control)	6.0	6.8	6.7	6.6	6.6
Overall average	**5.5**	**6.0**	**5.9**	**5.9**	**6.2**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 62: Ability to Disagree Productively Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.5	4.1	5.8	6.4	6.0
2 (treatment)	6.4	6.0	5.8	6.8	6.1
3 (treatment)	6.1	6.0	6.5	4.7	6.8
4 (treatment)	5.5	5.9	5.4	6.4	6.5
5 (control)	4.4	5.7	5.7	4.1	6.4
6 (control)	5.5	6.1	6.1	6.7	6.4
7 (control)	5.2	5.3	5.8	6.1	6.4
8 (control)	5.2	6.0	6.4	6.6	6.5
Overall average	**5.4**	**5.6**	**5.9**	**5.9**	**6.4**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 63: Defining a Common Purpose Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.4	5.6	5.6	6.7	6.8
2 (treatment)	6.4	5.9	5.6	5.5	6.5
3 (treatment)	6.2	5.7	6.6	5.0	4.7
4 (treatment)	5.4	5.9	6.0	6.9	6.4
5 (control)	4.6	5.2	5.2	3.7	6.4
6 (control)	5.7	6.5	6.1	6.4	6.7
7 (control)	5.1	4.9	5.8	6.3	6.3
8 (control)	5.7	6.4	6.7	6.6	6.8
Overall average	**5.5**	**5.8**	**5.9**	**5.8**	**6.3**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 64: Defining a Culture of Mutual Accountability Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	5.5	5.9	3.8	6.9	7.0
2 (treatment)	6.1	5.6	5.6	6.6	6.6
3 (treatment)	6.1	5.4	6.3	5.1	5.3
4 (treatment)	5.6	6.3	6.4	6.5	6.6
5 (control)	4.4	5.4	5.4	3.2	5.4
6 (control)	4.7	6.5	6.2	6.1	6.7
7 (control)	5.4	5.1	5.9	5.6	6.3
8 (control)	5.1	6.7	6.7	6.6	6.8
Overall average	**5.3**	**5.9**	**5.8**	**5.8**	**6.3**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 65: Productively Managed Disruption Average of Self-Reported Team Ratings, High School Students

Team	R1	R2	R3	R4	R5
1 (treatment)	3.9	3.5	3.6	5.0	6.1
2 (treatment)	6.0	5.5	5.3	5.8	6.4
3 (treatment)	5.7	5.3	6.6	5.9	6.0
4 (treatment)	5.5	6.1	5.4	5.9	6.4
5 (control)	4.5	6.1	4.7	4.2	6.4
6 (control)	4.3	5.5	6.7	6.2	5.9
7 (control)	4.8	4.9	5.7	5.9	6.3
8 (control)	4.5	5.2	5.7	5.7	4.3
Overall average	**4.8**	**5.3**	**5.5**	**5.6**	**6.0**

Note: Scale was from 1 (Not at all) to 7 (Completely)

High School Student Behavior Findings Summary

There were participation effects for both control and treatment groups of high school students. This was especially true for the observed behaviors, which showed statistically significant increases over the weekly sessions for both the control groups and treatment groups. In terms of the behaviors impacted, it is interesting to note that the control group showed increases over the four weeks observed in even more of the behaviors (6 of the 11) than the treatment group (5 of the 11).

When looking at the self-reported team ratings of the same measures, one sees a different picture. Only two of the behaviors, mutual respect and trust in moving towards a solution, showed significant differences between the two groups; in both cases, it was the control group that gave itself higher ratings from R1 to R5.

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. These behaviors were 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.

The R5 comparison allowed for a comparison between the control and treatment groups during their last 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 and presentations. Thus, R5 data give us a sense of the cumulative impact of the full twenty-hour intervention on collaborative behavior of control and treatment groups; if behavior differences would be expected to exist anywhere between the two groups, it would be during this last session at the culmination of the project.

Statistically significant behavioral differences for five of the eleven behaviors were observed in R5: shares leadership, being emotionally intelligent, mutual respect, the ability to disagree productively, and defining a common purpose. For all five, the treatment group had a significantly higher occurrence of these behaviors.

Early Career STEM Professional Behavior Findings

The tables in the first part of this section **(Table 66** through **Table 76)** show the observed behavior ratings by the researchers from R1 through R5; see Appendix C for the individual behaviors studied. A table is included for each of the eleven behaviors observed by the researcher, breaking down the number of times this particular behavior was observed for each team during each week. The overall sum of behaviors observed in each week is included at the bottom of the table.

In order to compare the groups on each behavior, statistical tests were run on the differences between the frequency and patterns of occurrence these behaviors were observed in control and treatment over the R1 to R5 period. If there was a statistically significant difference between the control and treatment groups, a line graph was included below the table. Tables without accompanying line graphs showed no statistically significant differences between control and treatment.

Based on the R1 to R5 totals, behaviors most commonly observed were being an active follower (see **Table 67**) and mutual respect (see **Table 70**). These were followed by empathic listening (see **Table 69**) and sharing leadership (see **Table 66**). The next highest totals were for emotionally intelligent behavior (see **Table 68**), defining a common purpose (see **Table 74**), and trust in moving towards a solution (see **Table 71**).

As mentioned above, there was a comparison of treatment and control groups in the frequency and pattern of the eleven behaviors from R1 to R5. Cross-tabulations were run looking at the percentage of individuals in the control and treatment groups engaging in each specific behavior, across weeks 1 through 5. This type of analysis was chosen since it allowed a direct comparison between the two groups, to see whether or not being in one group increased or decreased the likelihood of engaging in that particular behavior. The seven that showed a statistically significant difference include behaviors related to sharing leadership, being an active follower, emotionally intelligent behavior, empathic listening, mutual respect, trust in moving towards a solution, and being transparent in communication.

Comparison Between Control and Treatment by Behavior

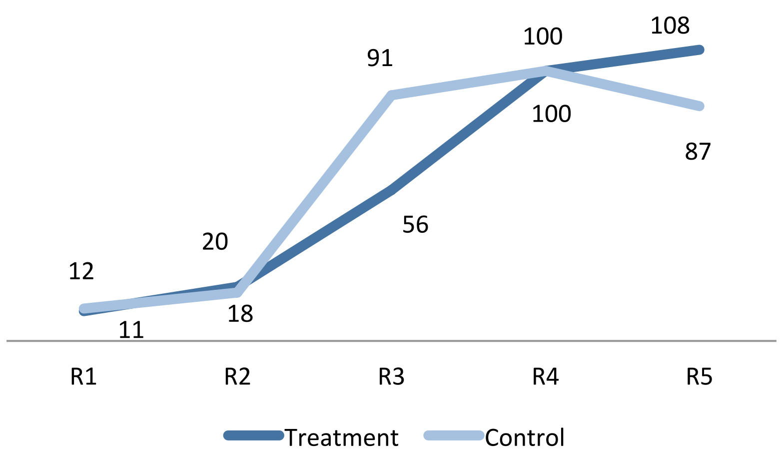
Shares Leadership

There were fewer occurrences of the behavior in R1 and R2, then higher occurrences in R3 through R5. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups. The control and treatment groups were very similar in R1, R2, and R4, the control group was higher in R3 and the treatment group was higher in R5. It is interesting to note that while the treatment group increases steadily each session from R1 to R5, the control group peaks at R4 and then declines in R5.

Table 66: Sum of Shares Leadership Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	7	8	10	27	24
2 (treatment)	2	4	18	22	28
3 (treatment)	1	1	14	20	29
4 (treatment)	1	5	14	31	27
5 (control)	0	5	21	26	24
6 (control)	6	4	26	32	26
7 (control)	4	3	28	24	22
8 (control)	2	8	16	18	15
Overall sum	**23**	**38**	**147**	**200**	**195**

Figure 10: Shares Leadership, Sum of Observed Behaviors in Groups Over Time, Early Career STEM Professionals



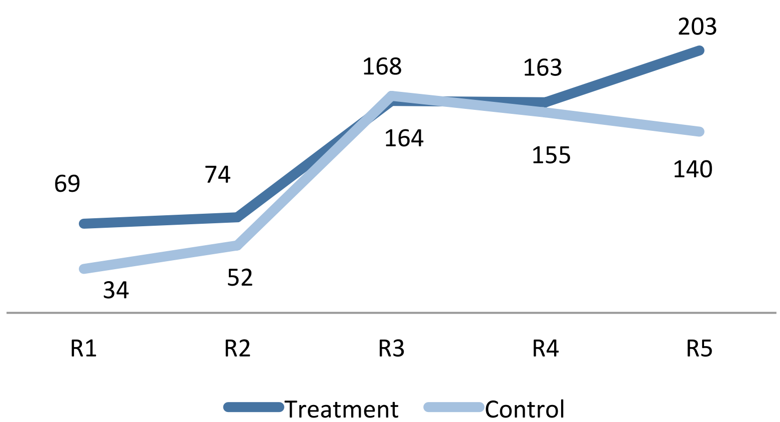
Active follower

Occurrences of this behavior increased in frequency each week between R1 and R3 (particularly in R3) and then essentially plateaued during the remaining sessions. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups. The treatment group was higher than the control group in R1 and R2, the control and treatment groups were very similar in R3 and R4, while the treatment group was higher than the control group in R5.

Table 67: Sum of Active Follower Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	22	22	38	44	50
2 (treatment)	12	17	53	34	49
3 (treatment)	20	15	40	35	52
4 (treatment)	15	20	33	50	52
5 (control)	7	13	37	40	35
6 (control)	8	15	47	40	35
7 (control)	14	13	50	44	41
8 (control)	5	11	34	31	29
Overall sum	**103**	**126**	**332**	**318**	**343**

Figure 11: Active Follower, Sum of Observed Behaviors in Groups Over Time, Early Career STEM Professionals

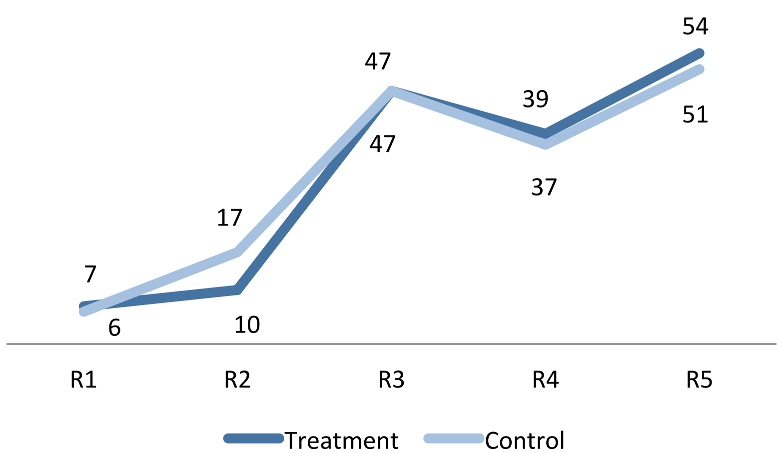


Emotionally intelligent behavior
There were lower occurrences for the behavior in R1 and R2, a large increase for R3, a slight decrease in R4, then another increase in R5. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups. While there was a higher occurrence for the control group in R2, the other weeks had very similar occurrences for the control and treatment groups. However, across the five sessions, the treatment group had a greater frequency of this behavior.

Table 68: Sum of Emotionally Intelligent Behavior Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	2	3	10	20	12
2 (treatment)	1	3	12	5	19
3 (treatment)	3	0	11	6	11
4 (treatment)	1	4	14	8	12
5 (control)	2	6	6	13	18
6 (control)	2	5	15	8	14
7 (control)	1	1	12	12	9
8 (control)	1	5	14	4	10
Overall sum	**13**	**27**	**94**	**76**	**105**

Figure 12: Emotionally Intelligent Behavior, Sum of Observed Behaviors in Groups Over Time, Early Career STEM Professionals



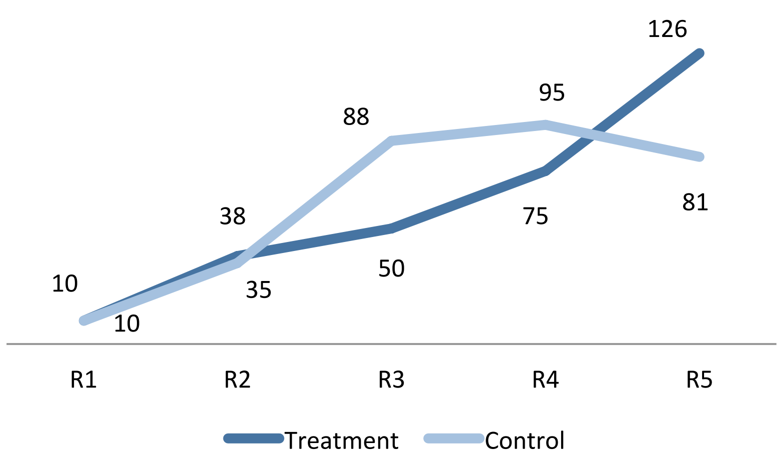
Empathic listening

There was a steady increase of occurrences of the behavior from R1 to R5, with ten times the number of occurrences comparing R1 to R5. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups. There was a very similar number of occurrences for the control and treatment groups for R1 and R2, higher occurrences for the control group in R3 and R4, then a higher occurrence for the treatment group in R5. It is interesting to note that while the treatment group increases steadily each session from R1 to R5, the control group plateaus at R3 and R4, and then declines in R5.

Table 69: Sum of Empathic Listening Behavior Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	3	11	11	21	28
2 (treatment)	3	9	17	13	40
3 (treatment)	2	8	14	17	28
4 (treatment)	2	10	8	24	30
5 (control)	2	11	14	22	21
6 (control)	3	7	29	26	19
7 (control)	2	7	24	31	21
8 (control)	3	10	21	16	20
Overall sum	**20**	**73**	**138**	**170**	**207**

Figure 13: Empathic Listening, Sum of Observed Behaviors in Groups Over Time, Early Career STEM Professionals



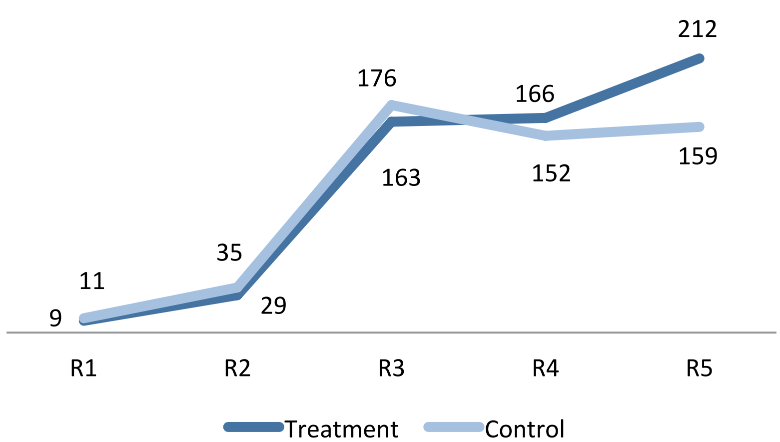
Mutual respect

There were lower occurrences for the behavior in R1 and R2, then much higher numbers of occurrences in R3 through R5. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups. While the number of occurrences was similar from R1 through R4, there was a higher number of occurrences for the treatment group in R5.

Table 70: Sum of Mutual Respect Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	5	13	36	45	54
2 (treatment)	2	4	46	35	54
3 (treatment)	1	3	43	36	54
4 (treatment)	1	9	38	50	50
5 (control)	3	8	39	40	39
6 (control)	3	7	48	40	40
7 (control)	5	9	54	45	45
8 (control)	0	11	35	27	35
Overall sum	**20**	**64**	**339**	**318**	**371**

Figure 14: Mutual Respect, Sum of Observed Behaviors in Groups Over Time, Early Career STEM Professionals



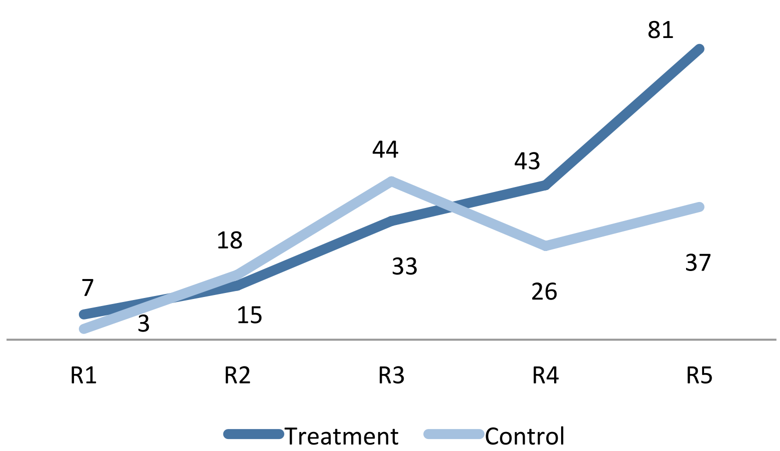
Trust in moving toward solution

There were lower number of occurrences of the behavior in R1 and R2, an increase for R3 and R4, then another increase for R5. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups. The control and treatment groups were similar for R1 and R2, the control group was modestly higher in R3, while the treatment group was higher in R4 and much higher in R5. The treatment group rose each week, while the control group declined considerably between R3 and R4.

Table 71: Sum of Trust in Moving Toward Solution Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	3	7	8	9	22
2 (treatment)	3	2	9	7	24
3 (treatment)	1	1	9	9	10
4 (treatment)	0	5	7	18	25
5 (control)	0	5	12	6	3
6 (control)	1	4	8	1	13
7 (control)	2	4	14	12	10
8 (control)	0	5	10	7	11
Overall sum	**10**	**33**	**77**	**69**	**118**

Figure 15: Trust in Moving Toward Solution, Sum of Observed Behaviors in Groups Over Time, Early Career STEM Professionals



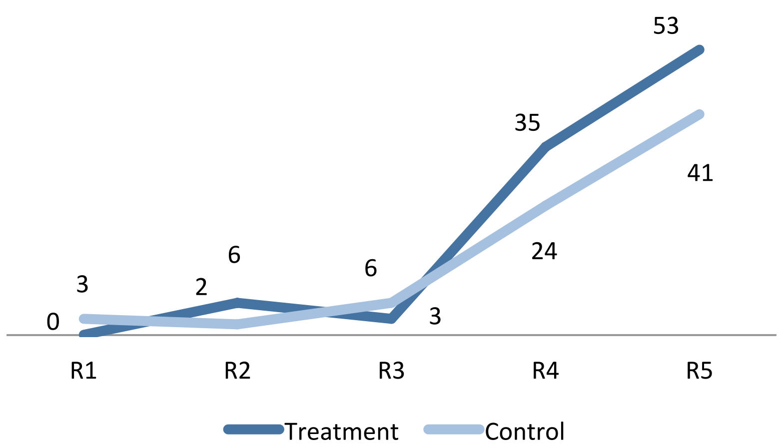
Transparent in communication

There were relatively few occurrences of the behavior in R1 to R3, with substantial increases in both R4 and R5. There was a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups. There were relative similar occurrences for the control and treatment groups for R1 to R3, then higher occurrences for the treatment group for R4 and R5.

Table 72: Sum of Transparent in Communication Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	0	0	0	11	13
2 (treatment)	0	2	0	8	11
3 (treatment)	0	1	1	3	8
4 (treatment)	0	3	2	13	21
5 (control)	0	1	1	5	9
6 (control)	2	0	2	5	11
7 (control)	1	1	2	5	14
8 (control)	0	0	1	9	7
Overall sum	**3**	**8**	**9**	**59**	**94**

Figure 16: Transparent in Communication, Sum of Observed Behaviors in Groups Over Time, Early Career STEM Professionals



Ability to disagree productively
There was a steady increase in the occurrence of behaviors from R1 to R5. There was not a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups.

Table 73: Sum of Ability to Disagree Productively Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	0	3	3	7	4
2 (treatment)	0	0	2	3	9
3 (treatment)	0	2	0	3	0
4 (treatment)	0	2	0	7	10
5 (control)	0	1	3	3	7
6 (control)	0	1	8	7	0
7 (control)	1	2	3	5	5
8 (control)	1	0	5	3	5
Overall sum	**2**	**11**	**24**	**38**	**40**

Defining a common purpose
There was a steady increase in the occurrence of behaviors from R1 to R5. There was not a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups.

Table 74: Sum of Defining a Common Purpose Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	4	3	3	14	16
2 (treatment)	1	3	13	6	11
3 (treatment)	4	3	5	8	12
4 (treatment)	2	7	5	10	16
5 (control)	2	6	9	7	8
6 (control)	3	3	16	16	11
7 (control)	2	3	11	14	14
8 (control)	1	10	10	9	10
Overall sum	**19**	**38**	**72**	**84**	**98**

Creating culture of mutual accountability

There were relatively low occurrences of the behavior from R1 to R5. There was not a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups.

Table 75: Sum of Creating Culture of Mutual Accountability Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	0	0	0	2	1
2 (treatment)	0	0	1	1	0
3 (treatment)	0	0	0	2	0
4 (treatment)	0	0	0	4	0
5 (control)	0	1	1	1	0
6 (control)	0	0	2	2	3
7 (control)	0	0	0	2	1
8 (control)	0	1	3	0	0
Overall sum	**0**	**2**	**7**	**14**	**5**

Productively manages disruption

There were less frequent occurrences of the behavior in R1 and R2, an increase in R3 and R4, then a decrease in R5. There was not a statistically significant difference in the frequency and pattern of the behavior between control and treatment groups.

Table 76: Sum of Productively Manages Disruption Behaviors Observed, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	2	1	0	9	4
2 (treatment)	0	0	0	8	4
3 (treatment)	0	0	0	5	3
4 (treatment)	1	0	0	5	3
5 (control)	0	0	4	8	4
6 (control)	2	0	8	9	3
7 (control)	2	0	5	8	4
8 (control)	0	2	6	2	3
Overall sum	**7**	**3**	**23**	**54**	**28**

Comparison between Control and Treatment in the Final Session

Looking at teams' behaviors over the course of the project allowed for an understanding of how the teams progressed during the weekly sessions. The final session, R5 represents the culmination of the project's innovation training, and looking specifically at the R5 outcomes gives us the ability to study the ways in which the collaborative behaviors of the control and treatment groups were impacted by the 20 hours of training.

In order to compare the comparative impacts of full the full 20-hour intervention, a statistical test was run, looking at the difference in the frequency of each of the eleven behaviors in R5, between the control and treatment groups.

Of the eleven comparisons, the following table shows two behaviors with statistically significant differences: mutual respect and trust moving toward a solution (see **Table 77**). Both of these showed a higher level of occurrence for the treatment group. Both control and treatment teams spent R5 finalizing their final presentations and business cases related to the challenge, so there were a lot of opportunities for collaborative behaviors. The treatment group engaged in these types of behaviors significantly more than the treatment group, suggesting that the treatment group was acting more collaboratively as they figured out the final pieces and details of their presentations.

Table 77: Summary Table of Observed Collaboration, Only for Week 5 (R5) (Pre/Post Observational Difference Scores)

	Early Career STEM Professionals	
Observational Category	**Statistically Significant Group Differences?**	**Group with Better Performance (Pre/Post)**
Shares leadership	No	-
Active follower	No	-
Emotionally intelligent behavior	No	-
Empathic listening	No	-
Mutual respect	Yes	Treatment
Trust in moving toward solution	Yes	Treatment
Transparent in communication	No	-
Ability to disagree productively	No	-
Defining a common purpose	No	-
Creating culture of mutual accountability	No	-
Productively manages disruption	No	-

Self-Reported Team Collaboration Ratings of Early Career STEM Professionals

The following tables are the individual self-reported team ratings of the adult participants of their own behaviors during each session. All but one of the measures saw an increase in the average rating from R1 to R5; shares leadership (see **Table 78)** showed neither an increase nor a decrease. The three biggest increases were an increase of 0.9 for being able to disagree and dispute productively (see **Table 85**), an increase of 0.6 for defining a common purpose (see **Table 86**), and creating a culture of mutual accountability. The highest ratings in the last week (R5) included mutual respect (see **Table 82**) and creating a culture of mutual accountability (see **Table 87**). These were followed by being an active follower (see **Table 79**), empathic listening (see **Table 81**), being transparent in communication (see **Table 84**), and defining a common purpose (see **Table 86**).

Table 78: Shares Leadership Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	6.4	6.6	6.7	6.2	6.0
2 (treatment)	6.0	5.6	6.2	6.0	6.6
3 (treatment)	5.8	5.7	6.1	5.8	6.6
4 (treatment)	6.6	6.4	6.5	6.6	6
5 (control)	6.3	6.6	6.2	6.6	3
6 (control)	6.2	6.9	6.9	5.4	6.9
7 (control)	5.6	6.1	6.0	6.8	6.2
8 (control)	5.4	6.7	6.7	5.4	7.0
Overall average	**6.3**	**6.3**	**6.4**	**6.1**	**6.3**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 79: Active Follower Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	6.4	6.4	6.0	6.3	5.9
2 (treatment)	6.2	5.3	6.6	5.9	6.4
3 (treatment)	5.8	5.8	6.0	6.1	6.3
4 (treatment)	6.6	6.3	6.5	6.4	6.6
5 (control)	6.5	6.4	6.2	6.7	6.9
6 (control)	5.5	6.1	6.6	5.9	6.2
7 (control)	5.4	5.8	5.7	5.8	6.9
8 (control)	5.9	6.0	6.4	5.9	5.7
Overall average	**6.0**	**6.0**	**6.2**	**6.1**	**6.4**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 80: Emotionally Intelligent Behavior Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	6.6	6.2	6.7	6.7	6.0
2 (treatment)	6.6	4.8	6.6	6.1	6.7
3 (treatment)	5.4	5.4	6.0	5.2	6.4
4 (treatment)	6.3	6.0	6.7	6.2	6.0
5 (control)	5.7	6.5	5.9	6.7	6.7
6 (control)	5.9	6.2	6.6	5.4	6.1
7 (control)	6.2	6.1	5.0	6.0	6.6
8 (control)	5.4	5.7	6.3	5.4	5.4
Overall average	**6.0**	**5.9**	**6.2**	**6.0**	**6.3**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 81: Empathic Listening Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	6.7	6.3	6.8	6.2	5.8
2 (treatment)	6.7	6.2	6.4	6.4	6.7
3 (treatment)	6.2	5.7	6.3	6.1	6.7
4 (treatment)	6.5	6.4	6.8	6.1	6.2
5 (control)	6.5	6.7	6.0	6.7	6.9
6 (control)	5.9	6.2	6.6	6.0	6.4
7 (control)	5.7	5.4	5.7	6.7	6.9
8 (control)	6.0	6.4	6.7	5.9	5.9
Overall average	**6.3**	**6.2**	**6.4**	**6.3**	**6.4**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 82: Mutual Respect Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	6.9	6.8	6.8	6.7	6.0
2 (treatment)	6.9	6.3	6.8	6.6	6.9
3 (treatment)	5.6	6.2	6.3	6.1	6.7
4 (treatment)	6.8	6.6	6.9	6.6	6.3
5 (control)	6.7	6.7	6.5	6.7	7.0
6 (control)	6.1	6.7	6.6	5.7	6.5
7 (control)	5.6	5.9	6.6	7.0	7.0
8 (control)	6.0	6.9	6.7	6.4	6.0
Overall average	**6.3**	**6.5**	**6.6**	**6.5**	**6.5**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 83: Trust in Moving Toward Solution Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	5.8	6.3	6.3	6.0	5.4
2 (treatment)	6.3	5.3	6.2	6.3	6.8
3 (treatment)	5.0	5.3	5.4	6.0	6.3
4 (treatment)	6.4	6.5	6.6	6.5	6.0
5 (control)	6.7	6.6	6.4	6.7	7.0
6 (control)	6.4	6.5	6.6	6.0	6.4
7 (control)	6.0	5.3	6.6	7.0	6.9
8 (control)	5.6	6.7	5.9	5.7	5.6
Overall average	**6.0**	**6.1**	**6.3**	**6.3**	**6.3**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 84: Transparent in Communication Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	6.7	6.7	5.8	6.8	6.1
2 (treatment)	6.4	6.0	6.7	6.2	6.7
3 (treatment)	6.0	5.8	6.1	5.9	6.6
4 (treatment)	6.5	6.3	6.6	6.5	6.8
5 (control)	6.5	6.7	6.2	6.8	7.0
6 (control)	6.1	6.6	6.7	5.4	6.2
7 (control)	6.1	5.7	6.7	6.8	6.8
8 (control)	5.3	6.6	6.4	6.0	5.1
Overall average	**6.2**	**6.3**	**6.4**	**6.3**	**6.4**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 85: Ability to Disagree Productively Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	6.6	5.2	6.6	6.8	6.0
2 (treatment)	5.2	6.0	5.9	5.1	6.4
3 (treatment)	3.9	4.0	5.7	5.3	6.0
4 (treatment)	6.4	5.5	6.6	5.9	5.8
5 (control)	4.3	6.7	5.9	6.0	7.0
6 (control)	4.9	5.9	5.7	5.1	6.4
7 (control)	4.4	4.9	5.6	5.2	5.8
8 (control)	5.3	6.4	5.6	5.9	5.9
Overall average	**5.2**	**5.5**	**6.0**	**5.7**	**6.1**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 86: Defining a Common Purpose Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	5.8	6.1	5.8	6.4	6.1
2 (treatment)	6.1	5.6	6.8	6.1	6.9
3 (treatment)	6.0	5.8	5.9	6.0	5.9
4 (treatment)	6.3	6.1	6.5	6.6	6.3
5 (control)	6.2	6.6	6.0	6.6	7.0
6 (control)	5.7	6.0	6.1	5.9	6.5
7 (control)	5.6	5.1	5.6	5.8	6.9
8 (control)	5.0	6.4	6.3	4.9	5.6
Overall average	**5.8**	**5.9**	**6.1**	**6.1**	**6.4**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 87: Creating Culture of Mutual Accountability Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	6.3	5.4	6.8	6.6	6.0
2 (treatment)	6.3	6.0	6.3	6.2	6.9
3 (treatment)	4.6	5.7	6.0	6.0	6.4
4 (treatment)	6.0	6.0	6.4	6.4	6.5
5 (control)	6.2	6.5	5.7	6.5	7.0
6 (control)	5.2	6.1	6.7	5.9	6.5
7 (control)	5.8	5.9	5.9	4.8	6.9
8 (control)	4.4	6.3	6.6	6.0	5.3
Overall average	**5.6**	**6.0**	**6.3**	**6.0**	**6.5**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Table 88: Productively Manages Disruption Average of Self-Reported Team Ratings, Early Career STEM Professionals

Team	R1	R2	R3	R4	R5
1 (treatment)	2.9	3.4	4.4	5.2	4.6
2 (treatment)	3.1	4.9	5.7	5.7	5.6
3 (treatment)	3.1	3.9	3.6	4.6	5.4
4 (treatment)	4.0	3.9	4.0	4.5	5.0
5 (control)	3.3	5.9	5.6	5.9	7.0
6 (control)	4.9	4.6	5.4	4.9	6.5
7 (control)	3.6	3.7	3.7	4.1	5.3
8 (control)	3.9	5.3	5.7	4.7	4.4
Overall average	**3.6**	**4.4**	**4.7**	**4.9**	**5.5**

Note: Scale was from 1 (Not at all) to 7 (Completely)

Early Career STEM Professionals Behavior Findings Summary

For the early career STEM professionals, there were differences in the weekly totals for the treatment groups in about two thirds of the observation behaviors, while only one behavior for the control group showed a statistically significant difference.

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.

For the self-reported team behaviors, there were no statistically significant differences for either the control or treatment group across the five sessions.

The R5 comparison allowed for a comparison between the control and treatment groups during their last 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 and presentations. Thus, R5 data give us a sense of the cumulative impact of the full twenty-hour intervention on collaborative behavior of control and treatment groups; if behavior differences would be expected to exist anywhere between the two groups, it would be during this last session at the culmination of the project.

Statistically significant behavioral differences for 2 of the 11 behaviors were observed in R5: mutual respect and trust in moving towards a solution. For both of these, the treatment group had a significantly higher occurrence of these behaviors.

Hypothesis 3 Findings: Team Innovation Outcomes

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

While Hypothesis 1 focused on individuals, and Hypothesis 2 focused on the team as the unit of analysis, Hypothesis 3 focused on the innovation outcomes of the teams by analyzing the prototype products, processes and services they developed.

The analysis was performed by a distinguished group of expert panelists, composed of three members of the selection committee of the Product Development Management Association (PDMA)'s Outstanding Corporate Innovation Awards, including that committee's founding and current Chairs.

The panel, consulting with the project and research teams, developed an assessment rubric identifying and weighting seven measures to gauge the quality of the innovation outcomes including team innovation outputs and work products. They subsequently applied the rubric to the new product, process and service solution concepts developed by the teams. All scores are based on a rating scale from 1-5 points. Each of the scales was given an overall weight, in order to calculate the relative importance of each for the total score.

1. Insight into Challenge: Grasp of transportation needs, conditions and opportunities. [Overall weight = 15%]
2. Clarity and Relevance of Problem [Overall weight = 15%]
3. Problem Solving Strategy [Overall weight = 25%]
4. Impact: assessed by value proposition, potential market size and penetration. [Overall weight = 15%]
5. Developmental Strategy [Overall weight = 10%]
6. Feasibility: Market, technology, capacity, cost, competition, risk/barriers etc. [Overall weight = 10%]
7. Teamwork/Collaboration: Integration of skills; distributed and collaborative effort [Overall weight = 10%]

The panelists met in person over two days at the Kelley School of Business at Indiana University to discuss and assess the product, process and service innovations created by the teams in response to the civic challenges (see Appendices J and K). The challenges included transportation alternatives for the high school students, water resources for the early career STEM professionals. Ahead of the panel meeting (but after the panel's completion of work on the assessment rubric), the panelists received the business cases created by each of the teams for their advance review; panelists were asked not to discuss these materials with their colleagues ahead of the meeting. During the course of the meeting, panelists reviewed three additional components: the PowerPoint presentations created by each team about its innovation, pre-recorded videos of each team's 5-minute concept presentation, and pre-recorded videos of each team's responses to a standardized set of questions. Taken together, these elements (business case, PowerPoint presentations, video of concept presentation and video of responses to questions) formed the basis for the panel's overall assessment of each team's innovation outcomes.

The classroom hosting the panel meeting was equipped with a two-screen setup, where each PowerPoint was projected on the left screen while the video of that team's presentation was projected synchronously on the right screen, with audio heard through the classroom's sound system. A project partner started the video on the right screen and then manually ran through the PowerPoint slides on the left to match where the team was in the video presentation. In this manner, the panelists were able to both watch the teams present and view their PowerPoint presentations at the same time, approximating the experience of being in the classroom when the teams gave their presentations.

The three-person review panel sat together in one row of the classroom, took notes and independently filled out rating sheets while viewing the presentations. After the video had finished, they completed the rating sheet without talking to each other. When all three panelists were done with their individual ratings for that team, they engaged in a discussion around the team's overall presentation, its approach to the problem, the proposed solution, and other topics on the rating sheets. After this group discussion was over, the panelists went back to their rating sheets and made any adjustments or rescoring of the sheets. The sheets were collected after the review of each team's presentation was completed. This same process was repeated for each team. Eleven teams were reviewed in this manner on the first day and five on the second day. The reviewers did not know which of the 16 groups were in the control or treatment condition, and the order of consideration of teams within each group (i.e., adults and adolescents) was randomized.

High School Students Findings

For high school students, the total weighted team innovation outcome scores varied greatly, ranging from a 1.3 to a 4.4 on a 5-point scale (see **Table 89**). Next, the scores of each item for each team in the control and treatment groups were combined, and the two sets of combined totals were compared (see **Table 90**).

Treatment outperformed control on all seven individual items scored. Four of these differences were statistically significant: insight into challenge (2.0 difference), clarity and relevance of the problem (1.7 difference), problem solving strategy (1.3 difference) and the potential impact of their proposal (1.3 difference). 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.

Table 89: Panel Scores for High School Students Team Final Products (Innovation Outcomes)

	Control				Treatment			
	Team 5	Team 6	Team 7	Team 8	Team 1	Team 2	Team 3	Team 4
Insight into challenge	2.8	1.0	1.3	2.3	5.0	1.7	3.0	3.3
Clarity and relevance of problem	3.3	1.3	2.7	2.7	5.0	1.7	4.0	3.0
Problem Solving Strategy	2.0	1.3	2.5	2.0	4.8	2.0	2.3	2.7
Impact	2.7	1.3	1.7	2.3	4.3	1.7	2.3	3.0
Developmental Strategy	3.0	1.0	3.5	3.8	3.7	1.3	3.3	2.7
Feasibility	2.3	1.3	3.0	3.3	3.3	1.3	4.0	2.0
Teamwork/ Collaboration	4.0	2.0	5.0	2.7	3.7	2.3	2.7	4.3
Total weighted score	**2.8**	**1.3**	**2.6**	**2.6**	**4.4**	**1.8**	**3.0**	**3.0**

Table 90: Average Panel Scores for High School Students Team Final Products (Innovation Outcomes), Control and Treatment

	Control	Treatment	Statistically Significant Difference?
Insight into challenge	1.8	3.8	**Yes**
Clarity and relevance of problem	2.3	4.0	**Yes**
Problem Solving Strategy	2.0	3.3	**Yes**
Impact	1.9	3.2	**Yes**
Developmental Strategy	2.5	3.2	No
Feasibility	2.3	3.1	No
Teamwork/Collaboration	3.2	3.6	No
Total weighted score	2.3	3.0	No

Early Career STEM Professionals Findings

For early career STEM professionals the total weighted team innovation outcome scores varied greatly, ranging from a 2.2 to a 4.2 on a 5-point scale (see **Table 91**). Next, the scores of each item for each team in the control and treatment groups were combined, and the two sets of combined totals were compared (see **Table 92**). While differences between control and treatment were found for the high school students on the individual items, 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.

Table 91: Panel Scores for Early Career STEM Professionals Team Final Products (Innovation Outcomes)

	Control				Treatment			
	Team 5	Team 6	Team 7	Team 8	Team 1	Team 2	Team 3	Team 4
Insight into challenge	3.7	3.0	3.7	4.0	3.0	3.7	2.0	4.0
Clarity and relevance of problem	4.0	3.3	3.3	3.7	3.3	3.2	3.0	4.3
Problem Solving Strategy	3.8	1.5	3.3	2.3	3.0	2.3	2.0	4.3
Impact	3.2	1.3	2.7	2.2	2.7	2.3	1.7	4.3
Developmental Strategy	2.7	1.6	3.0	2.7	2.0	2.2	1.3	4.3
Feasibility	3.7	1.8	2.2	2.8	2.5	2.8	2.0	4.2
Teamwork/ Collaboration	4.5	3.7	3.3	2.7	3.7	4.7	3.3	4.0
Total weighted score	**3.7**	**2.2**	**3.1**	**2.9**	**2.9**	**2.9**	**2.2**	**4.2**

Table 92: Average Panel Scores for Early Career STEM Professionals Team Final Products (Innovation Outcomes), Control and Treatment

	Control	Treatment	Statistically Significant Difference?
Insight into challenge	3.6	3.2	No
Clarity and relevance of problem	3.6	3.5	No
Problem Solving Strategy	2.7	2.9	No
Impact	2.3	2.7	No
Developmental Strategy	2.5	2.4	No
Feasibility	2.6	2.9	No
Teamwork/Collaboration	3.5	3.9	No
Total weighted score	3.0	3.0	No

The role of the expert panelists was to provide an objective assessment of the new products, processes and services conceptually developed by the teams over their 5-week courses of training (i.e., team innovation outputs). As such, panelists considered the extent to which each team was able to surface insightful thinking about the Innovation Challenge; identify a clear, relevant and productive problem to solve; find a novel and potentially impactful way to solve its chosen problem; outline a compelling developmental and go-to-market strategy for its innovation; and articulate a potentially feasible path from concept to implementation. In addition, 10% of each team's total weighted score was based on the panel's assessment of its integration skills through distributed and collaborative effort; an assessment that was necessarily inferential, since panelists had extremely limited opportunity to witness direct evidence of team collaborative processes, dynamics and decision-making.

Given that the panelists were not involved in or present during the training sessions in Worcester or San Diego and that they did not know which groups were control or treatment, their scoring was a good test of whether the integration of arts-based learning into innovation training impacted the kinds of new products, processes and services developed by the teams; and whether it impacted the ways teams creatively addressed STEM Innovation Challenges in their thinking about problems, solutions, novelty, value, impact, feasibility and other key concepts of innovation.

Team Innovation Outcomes Findings 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.

In contrast, there were no statistically significant differences between control and treatment groups reflected in the panelist ratings of the early career STEM professional teams. As mentioned earlier in the Limitations section of this report, 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.

The findings in this section show the powerful potential benefits of applying arts-based approaches to adolescent STEM innovation learning and practice. They also underline the critical need for further study to determine whether, and in what ways, adult findings would change with the substitution of a curriculum specifically designed for use with adults.

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Appendices

Appendix A: Pre Workshop Survey

Welcome to the Transportation Challenge!

We are so pleased to have as part of this project. As you know, this project is the research portion of a larger NSF grant on science and learning in informal contexts. The research is an integral portion of the project, and understanding who you are, what you think, and what you do is important information for making the project a success. This information is also important to understand whether projects of this type are worth your time and taxpayer money. This particular survey is critical to us going forward.

This survey should take approximately 20-30 minutes to complete. The questions in the survey are about you; there are no right or wrong answers. Please be assured that all of your responses will be kept confidential. None of the information you provide that could identify you individually will be included in the presentation of survey results. We would like to encourage you to take your time and answer the survey questions both as openly and honestly as you can.

We'd like to know you a bit better as you join this project. The next set of questions are background questions to better understand your outside interests, especially connections with science and art.

1. How often have you participated in the following activities in the last two years:

Activity	Not at all in the last two years	At least once in the last two years
Attended a live music, theater, or dance performance		
Performed in or practiced a specific art form (e.g., dance, singing, classical music, etc.)		
Attended an art museum or gallery		
Took a class or lesson (whether in or out of school) in an art form or art subject		
Emailed, posted, or shared artwork (your own or others; includes photos & music)		
Used TV, radio, or the Internet to access art or arts programming		
Attended a professional conference related to the arts		
Read an arts-focused blog		
Visited a crafts fair or a visual arts festival		
Taught an art class or lesson		
Read a science-focused blog		
Taught a science class or lesson		
Attended a professional conference related to science		

Attended a science museum
Performed a science experiment (informally or formally)
Used TV, radio, or the Internet to access science programming
Visited a science festival
Took a science class or lesson (whether in or out of school)
Emailed, posted, or shared scientific information (e.g., quote or article of interest, etc.)
Participated in an evening event at a science-based institution

2. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you agree or disagree with the following statements?**
   a) Occasionally I like to work on extremely difficult problems
   b) I only like tasks that have a high probability of success
   c) I do not share my ideas with others
   d) I often read books and magazines outside of my core interest area
   e) I sometimes use my dreams or daydreams as a source of new ideas
   f) I am not afraid of failure
   g) Daydreaming only wastes my time
   h) I do not like to work on problems that have no solution
   i) There are special places where I go to think
   j) I keep something by my bed at night, to record ideas
   k) I enjoy working with the same group of people all the time
   l) I do not need any more colleagues
   m) I seek training in new areas
   n) I make an effort to meet new people

3. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you agree or disagree with the following statements?**
   a) Almost every problem has a solution
   b) I like to fool around with new ideas, even if they are a total waste of time
   c) Nothing gets accomplished in this world unless you stick to some basic rules
   d) Usually, the more clearly defined rules a society has, the better off it is
   e) Personally, I tend to think that there is a right way and wrong way to do almost everything
   f) I don't need to finish a task before starting a new task
   g) Before any important job, I must know how long it will take
   h) In a problem-solving group it is always best to systematically attack a problem
   i) I do not like to get started in group projects unless I feel assured that the project will be successful

j) In a decision-making situation in which there is not enough information to process the problem, I feel very uncomfortable

4. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you agree or disagree with the following statements?**
   a) There is too much wasted time in the creative process
   b) Brilliant ideas come from single 'AHA!' moments, not from working through the creative process
   c) Emotions detract from effective communication
   d) It is always counterproductive when conflict arises during collaborative work
   e) A good communicator can communicate effectively the same way in every situation
   f) Collaboration is rarely worth the time it takes
   g) Not everyone is capable of creativity
   h) The less life experience you have the less you have to offer when collaborating with others
   i) People are more likely to produce effective solutions through competition, rather than through collaboration
   j) Individuals are more likely than groups to come up with truly original ideas
   k) A lot of people who think they are effective communicators just talk a lot
   l) To be creative you must be artistic
   m) Creativity is something done by individuals, not something that happens on a group level
   n) Communication is predominantly verbal
   o) People who are outgoing are naturally better communicators

5. **On a scale from 1 (Strongly disagree) to 5 (Strongly agree, please rate the following sentences:**
   a) I should do some prejudgment of my ideas before telling them to others.
   b) We should cut off ideas when they get ridiculous and get on with it.
   c) I feel that people at work ought to be encouraged to share all their ideas, because you never know when a crazy-sounding one might turn out to be the best.
   d) One new idea is worth ten old ones.
   e) Quality is a lot more important than quantity in generating ideas.
   f) A group must be focused and on track to produce worthwhile ideas
   g) Lots of time can be wasted on wild ideas.
   h) I think everyone should say whatever pops into their head whenever possible.
   i) I like to listen to other people's crazy ideas since even the wackiest often leads to the best solution.
   j) Judgment is necessary during idea generation to ensure that only quality ideas are developed
   k) You need to be able to recognize and eliminate wild ideas during idea generation.
   l) I feel that all ideas should be given equal time and listened to with an open mind regardless of how zany they seem to be.

m) The best way to generate new ideas is to listen to others then tailgate or add on.
n) I wish people would think about whether or not an idea is practical before they open their mouth.

6. **One more set of questions about how you like to tackle problems. On a scale from 1 (Strongly disagree) to 7 (Strongly agree) on these questions on your personality:**
    a) I like to get things started by getting involved, gathering information, questioning.
    b) I like imagining the possibilities and sensing all kinds of new problems and opportunities.
    c) I can see good and bad sides to almost any fact, idea or issue.
    d) I am comfortable with situations were not everything is clear.
    e) I'm willing to let others take care of the details.
    f) I tend to form quick associations, define problems and conceptualize new ideas, opportunities and benefits.
    g) I am good at in inductive reasoning, in pulling together seemingly unrelated observations into an integrated solution.
    h) I don't like going forward until I have a sound understanding of the situation.
    i) I would prefer not to have to prioritize among good or not fully understood alternatives.
    j) I prefer ideas rather than moving to action.
    k) I do best in situations where there is a single correct answer or best solution to a problem.
    l) I can sort through large amounts of data and pinpoint "what's wrong" in a given situation.
    m) I am confident of my ability to make a sound evaluation and select the best solution to a problem
    n) I tend to lack patience with ambiguity.
    I prefer not spending too much time thinking about other ideas and points of view, or how different problems relate to one another.
    o) I like becoming involved in new experiences.
    p) I like to try things out rather than "mentally test" them.
    q) I consider myself a risk-taker: I don't need to understand something completely before I act.
    r) I'm willing to try as many different approaches as necessary until I find one that is sufficiently acceptable to those affected by the problem.
    s) I tend to be enthusiastic, but can be impatient as I try to act on plans.

7. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you feel you are an innovator in your school work?**

8. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you feel you are an innovator in your professional life?**

9. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you feel you are an innovator in your personal life, including hobbies and interests?**

10. **Please explain your ratings on whether you see yourself as an innovator or not.**

11. **Working with other classes, we've learned that individuals have very different and personal definitions of innovation. What is your definition of innovation?**

You are almost done! The final set of questions are demographic in nature that we collect to know that a diverse sample of people participated within this project. Again, your responses will remain anonymous.

12. **Are you...**
    a) Male
    b) Female
    c) Other/Prefer not to say.

13. **Which ethnic category do you most identify with? (Please check ALL that apply) This information is important, as part of federal grant, we need to show we are reaching a balanced audience.**

    a) African American or Black
    b) American Indian or Alaska Native
    c) Asian
    d) Caucasian or White
    e) Hispanic or Latino
    f) Native Hawaiian or other Pacific Islander
    g) Other: (please specify)
    h) Prefer not to answer

14. **What is the highest level of education that you've completed? (Please check ONE)**
    a) Less than high school (I'm still enrolled in high school)
    b) Less than high school (I'm no longer enrolled in high school)
    c) High School/GED
    d) Community college/technical training or certificate
    e) College degree (BA/BS)
    f) Graduate or Postgraduate degree

15. **Thank you very much for completing this pre-survey. We are looking forward to your participation in the challenge over the coming weeks! If there is anything else you would like to share with us at this time please do so below.**

Appendix B: Post Workshop Survey

We have been so pleased to have you participate in this challenge! Now for the final reflection. We'd like to ask you some questions about you, your team, and your thoughts about the challenge.

As you know, this project is the research portion of a larger NSF grant on science and learning in informal contexts. The research is an integral portion of the project, and understanding who you are, what you think, what you can do is important information for making the project a success. This information is also important to understand whether projects of this type (research) are worth your time and taxpayer money. This particular survey is critical to the research.

This survey should take approximately 20-30 minutes to complete. The questions in the survey are about you; there are no right or wrong answers. Please be assured that all of your responses will be kept anonymous. None of the information you provide that could identify you individually will be included in the presentation of survey results. We would like to encourage you to take your time and answer the survey questions both as openly and honestly as you can.

1. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you agree or disagree with the following statements?**
    a) Occasionally I like to work on extremely difficult problems
    b) I only like tasks that have a high probability of success
    c) I do not share my ideas with others
    d) I often read books and magazines outside of my core interest area
    e) I sometimes use my dreams or daydreams as a source of new ideas
    f) I am not afraid of failure
    g) Daydreaming only wastes my time
    h) I do not like to work on problems that have no solution
    i) There are special places where I go to think
    j) I keep something by my bed at night, to record ideas
    k) I enjoy working with the same group of people all the time
    l) I do not need any more colleagues
    m) I seek training in new areas
    n) I make an effort to meet new people

2. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you agree or disagree with the following statements?**
    a) Almost every problem has a solution
    b) I like to fool around with new ideas, even if they are a total waste of time
    c) Nothing gets accomplished in this world unless you stick to some basic rules
    d) Usually, the more clearly defined rules a society has, the better off it is
    e) Personally, I tend to think that there is a right way and wrong way to do almost everything
    f) I don't need to finish a task before starting a new task
    g) Before any important job, I must know how long it will take

h) In a problem-solving group it is always best to systematically attack a problem
i) I do not like to get started in group projects unless I feel assured that the project will be successful
j) In a decision-making situation in which there is not enough information to process the problem, I feel very uncomfortable

3. On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you agree or disagree with the following statements?

a) There is too much wasted time in the creative process
b) Brilliant ideas come from single 'AHA!' moments, not from working through the creative process
c) Emotions detract from effective communication
d) It is always counterproductive when conflict arises during collaborative work
e) A good communicator can communicate effectively the same way in every situation
f) Collaboration is rarely worth the time it takes
g) Not everyone is capable of creativity
h) The less life experience you have the less you have to offer when collaborating with others
i) People are more likely to produce effective solutions through competition, rather than through collaboration
j) Individuals are more likely than groups to come up with truly original ideas
k) A lot of people who think they are effective communicators just talk a lot
l) To be creative you must be artistic
m) Creativity is something done by individuals, not something that happens on a group level
n) Communication is predominantly verbal
o) People who are outgoing are naturally better communicators

4. On a scale from 1 (Strongly disagree) to 5 (Strongly agree, please rate the following sentences:

a) I should do some prejudgment of my ideas before telling them to others.
b) We should cut off ideas when they get ridiculous and get on with it.
c) I feel that people at work ought to be encouraged to share all their ideas, because you never know when a crazy-sounding one might turn out to be the best.
d) One new idea is worth ten old ones.
e) Quality is a lot more important than quantity in generating ideas.
f) A group must be focused and on track to produce worthwhile ideas
g) Lots of time can be wasted on wild ideas.
h) I think everyone should say whatever pops into their head whenever possible.
i) I like to listen to other people's crazy ideas since even the wackiest often leads to the best solution.
j) Judgment is necessary during idea generation to ensure that only quality ideas are developed

k) You need to be able to recognize and eliminate wild ideas during idea generation.
l) I feel that all ideas should be given equal time and listened to with an open mind regardless of how zany they seem to be.
m) The best way to generate new ideas is to listen to others then tailgate or add on.
n) I wish people would think about whether or not an idea is practical before they open their mouth.

5. **One more set of questions about how you like to tackle problems. On a scale from 1 (Strongly disagree) to 7 (Strongly agree) on these questions on your personality:**
   a) I like to get things started by getting involved, gathering information, questioning.
   b) I like imagining the possibilities and sensing all kinds of new problems and opportunities.
   c) I can see good and bad sides to almost any fact, idea or issue.
   d) I am comfortable with ambiguity.
   e) I'm willing to let others take care of the details.
   f) I tend to form quick associations, define problems and conceptualize new ideas, opportunities and benefits.
   g) I excel in inductive reasoning, in distilling seemingly unrelated observations into an integrated solution.
   h) I don't like proceeding until I have a sound understanding of the situation.
   i) I would prefer not to have to prioritize among good or not fully understood alternatives.
   j) I prefer ideas rather than moving to action.
   k) I do best in situations where there is a single correct answer or optimal solution to a problem.
   l) I can sort through large amounts of data and pinpoint "what's wrong" in a given situation.
   m) I am confident of my ability to make a sound evaluation and select the best solution to a problem
   n) I tend to lack patience with ambiguity.
   I prefer not spending too much time thinking about other ideas and points of view, or how different problems relate to one another.
   o) I like becoming involved in new experiences.
   p) I like to try things out rather than "mentally test" them.
   q) I consider myself a risk-taker: I don't need to understand something completely before I act.
   r) I'm willing to try as many different approaches as necessary until I find one that is sufficiently acceptable to those affected by the problem.
   s) I tend to be enthusiastic, but can be impatient as I try to act on plans.

6. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you feel you are an innovator in your school work?**

7. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you feel you are an innovator in your professional life?**

8. **On a scale from 1 (Strongly disagree) to 7 (Strongly agree), to what extent do you feel you are an innovator in your personal life, including hobbies and interests?**

9. **Please explain your ratings on whether you see yourself as an innovator or not.**

10. **Has your perception of yourself as an innovator changed during your participation in this project? In what ways?**

11. **On a scale from 1 (Strong Negative impact) to 7 (Strong Positive Impact), to what extent did participating in the Transportation Challenge change:**
    a) your overall ability to think creatively?
    b) Whether and how you document ideas as they pop up?
    c) the way you brainstorm?
    d) originality of thinking?
    e) how you describe and elaborate on your thinking to others?
    f) how you work with a wide range of individuals?
    g) your comfort in placing yourself into difficult or unfamiliar situations?
    h) your comfort in ambiguous tasks?
    i) whether you think of yourself as creative?
    j) how many strategies you come up with when problem-solving?

12. **Now that the project is over, we would like you to rate the contribution of each member of your group to the completion of the tasks and overall project. Your ratings will be anonymous and will not be shared with other members of the group at any time. They will only be used for analysis purposes, and combined with other responses.**

Overall, during this project…	CONTRIBUTED VERY LITTLE 1	2	3	4	5	6	CONTRIBUTED A LOT 7
Member #1, Yourself:	❑	❑	❑	❑	❑	❑	❑
Member #2, Name:	❑	❑	❑	❑	❑	❑	❑
Member #3, Name:	❑	❑	❑	❑	❑	❑	❑
Member #4, Name:	❑	❑	❑	❑	❑	❑	❑
Member #5, Name:	❑	❑	❑	❑	❑	❑	❑
Member #6, Name:	❑	❑	❑	❑	❑	❑	❑
Member #7, Name:	❑	❑	❑	❑	❑	❑	❑
Member #8, Name:	❑	❑	❑	❑	❑	❑	❑

Thank you very much for completing our survey and this project! We really appreciate your time and thoughtfulness. Do you have any further comments, thoughts or questions for us?

Appendix C: Observation Rating

TEAM: ___ Date (dd/mm/yy): _______ Observer Initials: _______________

Each Observation Sheet represents one group observed ideally for 20-30 minutes during an on-task group time. Once observation begins, it doesn't stop even if they group veers off task.

GROUP ACTIVITY #: ________ Start time of Observation: ______ End Time of Observation: _______

	#1:	#2:	#3:	#4:	#5:	#6:	#7:	#8:	#9:	#10:	#11:
Participant Contribution to the Task Rating (1-7)	___	___	___	___	___	___	___	___	___	___	___
• Shares leadership according to knowledge /skill	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Active, engaged follower	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Emotionally intelligent behaviors, interpersonal relationships and dynamics	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Empathic listening (Openness to other points of view, acknowledges others views)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Mutual respect	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Trust in moving towards a solution	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Transparent in communications and information	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Ability to disagree and dispute productively	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Defining a common purpose (particularly at the solution, buy-in as an indicator)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Creating a culture of mutual accountability	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
• Productively manages disruption within the group, reframing context or direction	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Appendix D: Collaboration Rating

Name: _______________ Date (dd/mm/yy): _________ Group Number: __________

Please answer the questions below about your group as honestly as possible. The other group members will not see your responses and they will all be combined for analysis.

During today's task(s), our group…	Strongly Disagree 1	2	3	Neither Agree Nor Disagree 4	5	6	Strongly Agree 7
• Shared leadership between people, based on knowledge and skill	❑	❑	❑	❑	❑	❑	❑
• Did a good job following the intent of the group, rather than each person's individual thinking	❑	❑	❑	❑	❑	❑	❑
• Was aware of and took into account how each group member was feeling	❑	❑	❑	❑	❑	❑	❑
• Listened to and acknowledged everyone's points of view	❑	❑	❑	❑	❑	❑	❑
• Showed mutual respect to each other	❑	❑	❑	❑	❑	❑	❑
• Trusted that we would eventually come up with a good solution	❑	❑	❑	❑	❑	❑	❑
• Was transparent with each other when we communicated and shared information	❑	❑	❑	❑	❑	❑	❑
• Was able to disagree and dispute productively	❑	❑	❑	❑	❑	❑	❑
• Defined the common purpose we were working towards	❑	❑	❑	❑	❑	❑	❑
• Created a culture of mutual accountability, where we were all responsible for completing the task	❑	❑	❑	❑	❑	❑	❑
• Productively managed any disruption within the group (if applicable)	❑	❑	❑	❑	❑	❑	❑
• Was able to successfully complete the task(s) assigned to us today.	❑	❑	❑	❑	❑	❑	❑

Appendix E: Transferability Survey

It's been several months since your participation in the Worcester Innovation Challenge. Now that some time has passed, we'd like to ask you some questions about your participation.

1. **To what extent have you been thinking about what you learned about innovation and creativity during the Worcester Innovation Challenge Please check one only.**

Haven't thought about it at all	Thought about it once or twice	Have thought about it weekly	Have thought about it several times a week	Have thought about it daily

2. **What were your initial reasons for deciding to participate in the Challenge. What motivated you to do it?**

3. **Did participating in the Challenge have any effect on how you have been thinking about solutions for other topics or issues?**

1 – Not at all	2	3	4 – To some extent	5	6	7- A great deal

   a. **Can you give an example of how it has changed?**

4. **Do you feel in this workshop you had do activities that were out of your comfort zone?**

1 – Not at all	2	3	4 – To some extent	5	6	7- A great deal

   a. **Why did you give the rating you did?**

5. **To what extent have you been able to apply the Innovation Challenge experience to your <u>current</u> work or volunteer activities?**

1 – Not at all	2	3	4 – To some extent	5	6	7- A great deal	Not Applicable

6. **Which parts of the challenge have you been able to use in your <u>current</u> work or volunteer activities? Please give as many examples as you can.**

7. **To what extent do you think you will be able to apply your Innovation Challenge experience to your future work or volunteer activities?**

1 – Not at all	2	3	4 – To some extent	5	6	7- A great deal	Not Applicable

   a. **If yes, in what ways?**

8. **To what extent have you been able to apply the Innovation Challenge experience to your current school or extracurricular situation?**

1 – Not at all	2	3	4 – To some extent	5	6	7- A great deal	Not Applicable

9. **Which parts of the challenge have you been able to use in your current school or extracurricular activities? Please give as many examples as you can.**

10. **To what extent do you think you will be able to apply your Innovation Challenge experience to your future school or extracurricular situation?**

1 – Not at all	2	3	4 – To some extent	5	6	7- A great deal	Not Applicable

   a. **If yes, in what ways?**

11. **To what extent have you been able to apply your Innovation Challenge experience to your current home/personal life?**

1 – Not at all	2	3	4 – To some extent	5	6	7- A great deal

   a. **In what ways?**

12. **If you felt you benefited from this challenge, were particular attributes about your background or situation that made it useful to you? We're interested in whether those that benefit from this training have particular characteristics or background in common.**

13. **What was the one thing you experienced in the Challenge that you think will be most helpful to you in the future, and why?**

Appendix F: Pre Workshop Creativity Skills Task Worcester

Your Name: ___________________________________
Group: ☐ **Morning** ☐ **Afternoon**

Welcome to the Worcester Challenge! We're so pleased to have you here. We have a brief warm-up task that we need you to complete.

Your Warm-Up Challenge is as follows:
Worcester (substitute your town if you're not living in Worcester) needs transportation alternatives to enhance its economic productivity, connect its neighborhoods and communities, and improve the quality of life for its residents.

During the next 15 minutes, do the following:

A) List up to 5 specific problems related to this challenge that you'd like to fix.

1.

2.

3.

4.

5.

B) From that list above, select the one problem you would most like to fix, and **explain why you chose that particular problem** from the list you created. It may help to focus on the particular characteristic(s) of the problem that makes the problem you selected either particularly important or particularly fixable.

C) List up to 5 possible solutions to the problem you've chosen in answer ‘B’ above.

1.

2.

3.

4.

5.

D) From the list of 5 possible solutions, select the one solution you would most like to develop. **Explain why you chose this solution**, focusing on the particular characteristic(s) of the solution that seems to have made it most appropriate for addressing the problem, giving as much evidence as possible for your decision.

Appendix G: Pre Workshop Creativity Skills Task San Diego

Your Name: ___________________________________

Group: ☐ **Morning** ☐ **Afternoon**

Welcome to the San Diego Challenge! We're so pleased to have you here. We have a brief warm-up activity that we'd like you to complete.

San Diego's Innovation Challenge is as follows:

San Diego needs innovations that will reduce the gap between its regional water supply and the demands of its industrial, agricultural and residential users.

During the next 7 minutes, please:

A) List up to 5 specific problems related to this challenge that you'd like to fix.

1.

2.

3.

4.

5.

B) From that list, select the one problem you would most like to fix and briefly **explain why you chose that particular problem**. It may help to focus on characteristics of the problem you selected that make it either particularly important or particularly fixable.

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Your Name: ___________________________________

Group: ☐ **Morning** ☐ **Afternoon**

During the next 7 minutes, please:

C) List up to 5 possible solutions to the problem you've chosen as answer “B” on the previous page.

1.

2.

3.

4.

5.

D) From this list, please select the one solution you would most like to develop and briefly **Explain why you chose this solution**. Please focus on the characteristics of the solution you chose that motivated you to choose it, giving as much evidence as possible to support your decision.

Appendix H: Post Workshop Creativity Skills Task

We have so enjoyed these conversations over the last few weeks. As one of the closing activities, we'd like you to work on another quick task.

Your Wrap-Up Challenge is as follows:
Imagine a town similar size and composition of Worcester/San Diego, where twenty percent of the population is affected by food insecurity, lacks fair and equitable access to a sufficient quantity of affordable, nutritious food for all citizens.

During the next 7 minutes, do the following:

A) List up to 5 specific problems related to this challenge that you'd like to fix.

1.

2.

3.

4.

5.

B) From that list above, select the one problem you would most like to fix, and **explain why you chose that particular problem** from the list you created. It may help to focus on the particular characteristic(s) of the problem that makes the problem you selected either particularly important or particularly fixable.

During the next <u>7 minutes</u>, do the following:

C) List up to 5 possible solutions to the problem you've chosen in answer 'B' above.

1.

2.

3.

4.

5.

D) From the list of 5 possible solutions, select the one solution you would most like to develop. **Explain why you chose this solution**, focusing on the particular characteristic(s) of the solution that seems to have made it most appropriate for addressing the problem, giving as much evidence as possible for your decision.

Appendix I: Creativity Skills Task Rubric

Section A: List up to 5 problems

Each problem will be scored either 0 or 1, as per the scoring table below. A total, from 0 to a maximum of 5 points, will be assigned for each respondent.

SCORE 1: Section A Scoring Table

0 points	1 point
• Restatement of another problem on the list • Answer not focused on the topic • Listed only solutions • Comments about how to go about identifying problems or solutions • Comments suggesting the participants did not read or understand the instructions	1 point per distinct problem meeting the following five criteria (no partial credit per problem). • The intent of the problem statement is reasonably clear • The problem statement is not just a restatement of the challenge • A problem is stated, rather than a solution • The problem is distinct from others identified by the same person • The problem relates to the challenge Example: *Car pollution and fumes* *Damaged roads* *Slow construction* *Bike and car accidents* *Slow moving traffic* *Maximum possible score of 5.*

SCORE 2: Idea Cluster

The Idea Cluster is a categorical code, with multiple categories possible. For optimum coding purposes, there will be no more than 10 categories. This code is a level higher than the distinct solution, so that multiple distinct problems may fit within a single idea cluster. For example, idea clusters within Transportation problem sets may include, but are not limited:

- Safety
- Poor environmental conditions (such as pollution)
- Poor quality public spaces
- Availability of public transportation
- Affordability of public transportation

Section B: Explain why you chose the problem

SCORE 3: Strength of Problem Statement 0-2 scoring to keep people in the game as much as possible. In order to keep people in the game as much as possible, a problem not previously listed in Section A is given equal weight to one that was listed in Section A. Further, a score of 1 is given to an aligned problem even if its expression is inferential in nature, so long as it is clear, specific and distinct. If the individual receives above a score of zero, move on to score 4.

- 2 = a clear, distinct, specific, explicitly worded problem aligned to the challenge.
- 1 = a clear, distinct, specific problem aligned to the challenge but inferential in expression.
- 0 = a response that failed to meet the criteria for 1 or 2 points.

SCORE 4: A count of each valid/logically-connected reason given for choosing the problem- one point per reason. There is no limit to the possible score.

SCORE 5: A count of the different rationales for the problem choice offered (categorical and multiple categories possible): impact, feasibility, personal engagement, originality/uniqueness, ancillary benefits. These should also be coded by category. Note: an answer might have multiple reasons coded as the same category, and should only receive one point per different rationale category.

Section C: List up to 5 solutions (see note below about match between Section C and Sections A/B

Each solution will be scored 0 or 1, as per the scoring table below.

SCORE 6a: Section C Scoring Table

0 points	1 point
• Restatement of challenge • States a problem rather than a solution • Restates another solution on the list • Answer vague or not focused on the topic • Comments about how to go about identifying problems or solutions • Comments suggesting the participants did not read or understand the instructions	1 point per distinct solution meeting the following four criteria (no partial credit per solution). • The intent of the solution statement is reasonably clear • The solution statement goes beyond the purely aspirational • The solution statement clearly represents a "how" response to the problem identified in B • The solution is distinct from others identified by the same person 1 point per distinct solution (no limit). Example: *Increase public bus schedule* *Decrease price of bus ticket* *Increase number of buses*

SCORE 6b

0 points	1 point
• Restatement of challenge • States a problem rather than a solution • Restates another solution on the list • Answer vague or not focused on the topic • Comments about how to go about identifying problems or solutions • Comments suggesting the participants did not read or understand the instructions	1 point per distinct solution meeting the following four criteria (no partial credit per solution). • The intent of the solution statement is reasonably clear • The solution statement goes beyond the purely aspirational • The solution statement clearly represents a "how" response to some challenge-related problem other than the problem identified in Section B. • The solution is distinct from others identified by the same person 1 point per distinct solution (no limit). Example: *Increase public bus schedule* *Decrease price of bus ticket* *Increase number of buses*

SCORE 6c – total of 6a and 6b

Section D: Explain why you chose the solution

Score 7: Solution Statement Strength

0-2 scoring to keep people in the game as much as possible. In order to keep people in the game as much as possible, a solution not previously listed in Section C is given equal weight to one that was listed in Section C. Further, a score of 1 is given to an solution aligned with a different problem, so long as that problem is aligned with the challenge. If the individual receives above a score of zero, move on to score 8.

- 2 = a clear, distinct, specific possible solution that addresses the challenge by solving the problem previously identified in Section B.
- 1 = a clear, distinct, specific possible solution that addresses the challenge by solving some other challenge-related problem
- 0 = a response that failed to meet the criteria for 1 or 2 points

SCORE 8: Count of the number of reasons given, including number of "evidence" statements when they are there without reasons

SCORE 9: **Type of Rationale offered for Solution Choice**(categorical and multiple categories possible): impact, feasibility, personal engagement, originality/uniqueness, comparative analysis, ancillary benefits.

SCORES 10 & 11: Specificity of Solution

- What (specifically) does the participant propose to do. (assign 0 points for unclear/incoherent proposal, 1 point for clear but without detail, 2 points for additional level of detail).
- How (specifically) does the participant propose to do it. (assign 0 points of the question is not addressed, 1 point for a generic/non-specific way of addressing it, 2 points for additional specificity).

SCORE 12: Idea Clustering

The Idea Cluster is a categorical code, with multiple categories possible. This code is a level higher than the distinct solution, so that multiple distinct solutions may fit within a single idea cluster. For example, idea clusters within Transportation problem sets may include, but are not limited:

- Safety
- Improved environment conditions (such as pollution)
- Improved public spaces
- Availability of public transportation
- Affordability of public transportation

Additional details:

- Students are eligible to receive credit for an answer to B or D even if they did not complete A or C if they stated or implied a problem/solution.

Appendix J: Business Case

Team number: _____________

PROBLEM STATEMENT:

SOLUTION TITLE:

1. **SOLUTION OVERVIEW –** Describe the specific solution you want to develop.

2. **RELEVANCE –** How is the proposed solution relevant to the *[Worcester transportation challenge/San Diego water challenge]?*

3. **NEWNESS – Describe specifically how the solution is new or innovative.**

4. **MARKET**
   a. Who is the customer?

   b. What is the value proposition? Why will customers buy this innovation?

   c. How large is the potential market?

d. How many customers will have purchased this after one year on the market?

e. How much will your customers be willing to pay for your innovation?

f. What is the basis for your estimates to c, d and e above?

5. **IMPACT – What's the case for your innovation having a significant direct impact on the challenge?**

6. **FEASIBILITY**
   a. What key steps are needed to develop your solution from concept to market? How long would they take?

   b. Are there obstacles that call into serious question the feasibility of the proposed solution? How might you address them?

   c. What skills will be needed for the development team?

   d. Are there potential partners who could help?

   e. How will your innovation generate revenues to sustain itself in the market?

Appendix K: Output Scoring Sheet

Panelist/Reviewer name: _________________ **Group number ID: _____________**

1. INSIGHT INTO CHALLENGE - Grasp of transportation needs, conditions and opportunities. [Overall weight = 15%]

5	Outstanding (Concept shows exceptional insight into actual conditions and opportunities, and meets significant unmet needs)
4	
3	Acceptable (Concept addresses the challenge by solving relevant unmet problems/needs)
2	
1	Limited (Concept deficient in its lack of grounding in actual conditions or failure to address relevant unmet needs)

Initial Rating: ________ **Rating after discussion:** ______________

Comments:

2 - CLARITY AND RELEVANCE OF PROBLEM [Overall weight = 15%]

5	Outstanding (Problem is very clearly defined and relevant to the challenge)
4	
3	Acceptable (Problem definition has reasonable clarity and relevance)
2	
1	Limited (Problem as stated is unclear or irrelevant to the challenge)

Initial Rating: __________ **Rating after discussion:** ______________

Comments:

3 - PROBLEM SOLVING STRATEGY [Overall weight = 25%]

5	Outstanding (Solution is a highly original and potentially fruitful way of addressing the problem)
4	
3	Acceptable (Solution has elements of novelty and seems likely to partially address the problem)
2	

1	Limited (Solution lacks novelty or is unlikely to meaningfully address the problem)

Initial Rating: _________ **Rating after discussion:** ______________
Comments:

4 - IMPACT: assessed by value proposition, potential market size and penetration. [Overall weight = 15%]

5	High (Solution delivers compelling value to a substantial number of clearly defined customers)
4	
3	Medium (Team successfully articulates a credible value proposition to an identified customer base)
2	
1	Low (Solution fails to deliver significant value or credibly identify a customer base)

Initial Rating: _________ **Rating after discussion:** ______________
Comments:

5 - DEVELOPMENTAL STRATEGY [Overall weight = 10%]

5	High (Clear evidence of integration of skills and effort)
4	
3	Medium (Appropriate collaborative behavior demonstrated)
2	
1	Limited (Evidence of bad teamwork or collaborative dysfunction)

Initial Rating: _________ **Rating after discussion:** ______________
Comments:

6 - FEASIBILITY: Market, technology, capacity, cost, competition, risk/barriers etc. [Overall weight = 10%]

5	High
4	
3	Medium
2	
1	Low

Initial Rating: __________ **Rating after discussion:** ______________

Comments:

7 – TEAMWORK/COLLABORATION: Integration of skills; distributed and collaborative effort [Overall weight = 10%]

5	High (Clear evidence of integration of skills and effort)
4	
3	Medium (Appropriate collaborative behavior demonstrated)
2	
1	Limited (Evidence of bad teamwork or collaborative dysfunction)

Initial Rating: __________ **Rating after discussion:** ______________

Comments:

Appendix L: Inter-rater Reliability Scoring for Creativity Skills Test

Question	Score
Creativity Score 1: 1	1
Creativity Score 1: 2	1
Creativity Score 1: 3	1
Creativity Score 1: 4	1
Creativity Score 1: 5	1
Creativity Score 2: 1	0.652
Creativity Score 2: 2	0.652
Creativity Score 2: 3	1
Creativity Score 2: 4	1
Creativity Score 2: 5	1
Creativity Score 3	
Creativity Score 5: Impact	0.75
Creativity Score 5: Feasibility	0.75
Creativity Score 5: Personal Engagement	1
Creativity Score 5: Originality/Uniqueness	1
Creativity Score 5: Comparative Analysis	1
Creativity Score 5: Ancillary Benefits	1
Creativity Score 6a: 1	1
Creativity Score 6a: 2	1
Creativity Score 6a: 3	1
Creativity Score 6a: 4	1
Creativity Score 6a: 5	1
Creativity Score 6b: 1	1
Creativity Score 6b: 2	1
Creativity Score 6b: 3	1
Creativity Score 6b: 4	1
Creativity Score 6b: 5	1
Creativity Score 7	1
Creativity Score 9: Impact	1
Creativity Score 9: Feasibility	1
Creativity Score 9: Personal Engagement	1
Creativity Score 9: Originality/Uniqueness	1
Creativity Score 9: Comparative Analysis	1
Creativity Score 9: Ancillary Benefits	1
Creativity Score 10: What	
Creativity Score 10: How	1
Creativity Score 12: 1	0.652
Creativity Score 12: 2	1
Creativity Score 12: 3	0.652
Creativity Score 12: 4	1
Creativity Score 12: 5	1

Appendix M: Idea Cluster Categories for Creativity Skills Test

Idea Clusters for Pre Creativity Skills Test, High School Students

1. Social Connection between neighborhoods
2. Access – schedules/ distance mostly related to public transportation, access for those with disabilities
3. Safety – of driving, public transportation, walking, biking, cleanliness of transportation
4. Environment – pollution caused by transportation
5. Infrastructure – roads, sidewalks, bike lanes, construction, repair, design
6. Alternatives – shared transportation, alternative fuel sources, bikes
7. Public transportation – new or revamped buses, subways, trollies
8. Government – legislation about transportation, subsidies, grants, laws, taxes
9. Traffic – related to driving
10. Economic – cost of transportation
11. Misc. – technology, stress, resources, education, advertising

Idea Clusters for Post Creativity Skills Test, High School Students

1. Access – farmers markets, grocery stores, location, safety, availability
2. Economic – food cost, cost of living, discounts
3. Education & Awareness- classes, campaigns, commercials, information
4. School – food programs, change lunch plan, classes in school (home ec, gardening)
5. Community Effort – locality, charity, community gardens, buying or growing food together
6. Agricultural – farming, crops, GMOs, chemicals, runoff, pollution, vertical farming, labeling
7. Health – obesity, nutrition, vitamins, etc.
8. Government Action
9. Infrastructure of Food Supply – transport and supply of food
10. Food Waste
11. Misc. – examples: overpopulation, water supply, tech, research, jobs

Early STEM Professionals

Idea Clusters for Pre Creativity Skills Test, Early STEM Professional

1. Collection (and Loss) of Earth's water – salt, rain, storm, desalination, general "runoff" comments
2. Recycle/Reuse household water – greywater, shower, toilet, tap, washing machine, drinking
3. Government Action – tax incentives, regulations, subsidies, laws, mandates, water value, emergency
4. Conservation (and Waste) – water filters, products such as showerheads or ½ flush toilets, community contests, household metering
5. Agricultural Use
6. Residential Use – lawns, gardens, native plants, "landscape" in some instances
7. Industrial Use
8. Infrastructure – comments about (in)efficiency, transport, piping, concrete, etc.
9. Education and Awareness – includes comments about advertising and branding
10. Pollution (and Purification) – e.g. "contamination" and "clean water supply"
11. Misc. – energy, composting, oil & gas usage, "food industry", environmental detriment (aquatic ecosystems), selfishness of people

Idea Clusters for Post Creativity Skills Test, Early STEM Professional

1. Access – farmers markets, grocery stores, location, safety, availability
2. Economic – food cost, cost of living, discounts
3. Education & Awareness- classes, campaigns, commercials, information
4. School – food programs, change lunch plan, classes in school (home ec, gardening)
5. Community Effort – locality, charity, community gardens, buying or growing food together
6. Agricultural – farming, crops, GMOs, chemicals, runoff, pollution, vertical farming, labeling
7. Health – obesity, nutrition, vitamins, etc.
8. Government Action
9. Infrastructure of Food Supply – transport and supply of food
10. Food Waste
11. Misc. – examples: overpopulation, water supply, tech, research, jobs