AC 2011-1734: ART2STEM: BUILDING A STEM WORKFORCE AT THE MIDDLE SCHOOL LEVEL

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Art2STEM: Building a STEM Workforce at the Middle School Level

1. Introduction

Art2STEM is an Innovative Technology Experiences for Students and Teachers (ITEST) - Strategy Project funded by the National Science Foundation (NSF), and it is currently in its second year. Project partners are Alignment Nashville, PENCIL Foundation, Metropolitan Nashville Public Schools (MNPS), Adventure Science Center, Tennessee Tech University, and Edvantia. Through the project, 7th – 9th grade girls learn that creative design, analysis, and product development (with tools such as Alice™, Spore™, SolidWORKS™, Rapid Prototyping, etc.) are an important part of the world of Science, Technology, Engineering, and Mathematics (STEM). The project partners of Art2STEM anticipate that girls who participate through after-school programs, industry visits, summer camps, and extensive university activities develop a deep awareness and sustained interest in STEM for their own future and career. Project deliverables are measured and assessed in formative and summative settings. Based on the feedback received from the project's evaluation, continuous improvement of Art2STEM is discussed by the project partners in weekly Implementation Team meetings and corrective actions are produced and implemented in the key deliverables of the project. The current situation of Art2STEM and the recent results of the project's progress and evaluation are highlighted in this paper.

2. Background

Starting in 2006 MNPS began plans to restructure its comprehensive high schools into wall-to-wall academies. As planning and implementation proceeded those who were leading the effort discovered an extremely low level of interest among middle school students to participate in STEM-related career academies in high school, while interest in other career academies like arts and entertainment was extremely high, especially among girls. In general concept, the MNPS academies are small schools within a larger high school that incorporate academics within a career focus. If low interest in STEM-related academies persisted, one of the principal goals of highs school redesign - to align the career focus of the academies with the projected workforce demand and needs of the area - at great risk due to low enrollment[1].

The Art2STEM project (http://art2stem.org) uses design, modeling, virtual reality, and rapid prototyping as tools to engage student interest in art and to structure a journey of exploration for middle school girls so that they will discover how their interest in art can be complemented and enhanced by STEM. To be successful, the project leadership team has recognized that teachers who influence the students daily must also participate and understand the connection of art and design to STEM career fields.

Six high schools and seven of their feeder middle schools were established as Art2STEM project sites. Activities at each site were facilitated by teams of "coaches." Forty-two coaches participated during the initial year of the project, including 18 middle school teachers, 6 high school teachers, and 18 community-based mentors. The Art2STEM project provided coaches with a variety of professional development opportunities that focused on project orientation, pedagogical frameworks (*How People Learn*[2] and Ford PAS[3]), and technical tools (SPORE

Creature Creator[4], Alice Virtual Reality programming, 3D Modeling software, and Rapid Prototyping). All of the Art2STEM coaches who completed the 2009-2010 school year participated in at least one of the professional development offerings, and most (71%) participated in three or more sessions.

The Art2STEM program offered a variety of activities for students, including up to 16 after-school sessions, 2 business field trips, a visit to Tennessee Tech University (TTU) and its rapid prototyping lab, parent nights, and a summer camp. Student ratings of the fun and learning experienced at program activities were consistently high.

A key program component of Art2STEM was the integration of student visits to local businesses and colleges. These experiences helped students learn about STEM-related jobs and careers and envision themselves in such professions. Sixteen businesses engaged with Art2STEM, with fourteen hosting site visits for students. In the spring of 2010, project evaluators developed and piloted a checklist designed to record the characteristics of those business visits. The results suggest that the tool may serve as a good communication instrument with businesses to convey objectives for business visits as well as to document business visit experiences. The checklist data from 2009-2010 suggest that business visits have tended to demonstrate some steps of the engineering cycle less often than others, including prototyping and testing functions.

3. Implementation Strategies

In order to accomplish project objectives, the Art2STEM project plan integrates several key concepts or components as foundational to its success. These include the following:

3.1. An Emphasis on Creative Arts: Art2STEM endeavors to tap into girls' talents and interests in the creative arts and illuminate how their creativity can be applied in the context of STEM careers. The project acknowledges that girls have considerably more exposure to and often articulate future careers in the arts and entertainment. Yet the activities are designed to take them on a transformational journey to experience and visualize new career options.

3.2. Intentional After-School and Summer Camp Activities: Art2STEM promotes learning in informal environments and provides real-world inquiry- and problem-based learning experiences that illuminate the engineering design process and use of innovative technology. Camp experiences provide opportunities to explore STEM topics in more breadth and depth. The implementation is solidly anchored on a pedagogical approach consistent with *How People Learn.* The program's activities are designed to authentically engage the girls in the engineering design process, including rapid prototyping.

3.3. Authentic Contexts: Girls will not choose STEM careers unless they can visualize themselves in that role. In order to do so, the individual skills learned in the clubs must be connected to real-world applications. The transfer of creativity must be evident to the girls. Art2STEM incorporates visits to local industries to provide the career context to help girls make this link. PENCIL Foundation leads efforts to engage businesses in the project and to strengthen and diversify the relationships between business and the academies.

3.4. Mentors, Role Models, and Community Infrastructure: The activities are facilitated by teams of 4-6 "coaches." Most schools' coaching teams consist of math and science teachers, two from the middle school and one from the zoned high school, and 2-3 "mentors" recruited by Adventure Science Center. Another key objective of the project is to provide mentors and role models for the girls. Adventure Science Center recruits college students majoring in STEM fields and professional women from local STEM-related businesses to serve as "mentors."

4. Art2STEM Activities

Art2STEM activities are created and planned by the coaches. Session dates and times are then entered into the project calendar for additional planning and tracking. Snacks and drinks are provided at the beginning of the two-hour, after school club meetings. One of the early activities of each project phase is Rapid Prototyping, which will be described in this section[6].

In one session, students create hand-made models using Play-Doh. During this time, students form any kind of Play-Doh animals or creatures using their brainstorming and creativity skills. See Figure 1.

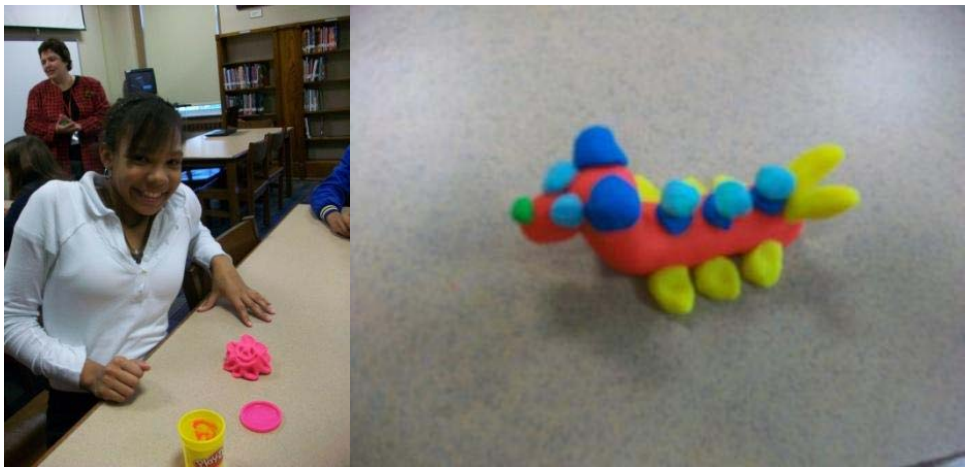

Figure 1: Play-Doh Activity

In the following session, using SPORE Creature Creator software, students learn to create and animate various creatures. And finally, each girl creates and animates her own creature using the SPORE software. Individually created creatures are then saved as electronic files, which are then emailed to Tennessee Tech University and Z Corporation where the creatures are rapid prototyped into 3D models. The completed models are then mailed to the students for display at school and at Art2STEM Family Night. See Figure 2.

In a subsequent session, middle school clubs visit Tennessee Tech University's Rapid Prototyping Laboratory[7] and spend a full day with hands-on Rapid Prototyping activities. Each girl observes the 3D printing process as models of human hands are made. Girls are then able to select, clean, design, and keep their 3D model hands. See Figure 3.

Figure 2: SPORE Creature Modeling and Simulation Activity

Figure 3: Rapid Prototype Your Own Hand Activity at Tennessee Tech University

5. Evaluation

Evaluation efforts focus on participating girls' attitudes, knowledge, and perceptions of STEM-related concepts, education, and careers. The evaluation outcome includes data from student focus groups, surveys, timeline exercises, and Draw An Engineer Tests (DAETs). The surveys, timelines, and DAETs were administered at the beginning and end of the 2009-2010 school year as well as at the end of camp during the summer of 2010. The focus groups were conducted in late May 2010 and during the last day of 2010 summer camp. Results from the student focus groups and open-ended survey items suggested that Art2STEM participation contributed to mostly positive shifts in the girls' attitudes and knowledge related to STEM. Feedback from two open-ended survey items suggested five inter-related themes:

- STEM topics are not boring;
- STEM topics are important and widespread;
- STEM careers are accessible;
- STEM careers are appealing; and

- STEM is still or now unappealing (for a subset of the girls).

Results from the focus groups suggested that for most girls, Art2STEM participation increased their interest in science and engineering; improved their understanding and appreciation of engineering, science, technology, and math; and increased their interest in and likelihood of considering STEM education and careers. Their feedback also suggested changes that Art2STEM might consider in order to make the program more appealing, including increasing emphasis on math and science, adding more hands-on activities, and reducing data collection.

The student survey findings suggest that the most apparent change over time related to the girls' understanding of what engineers and scientists do. The students in both samples - core students and summer campers - demonstrated statistically significant increases in understanding that were consistent across items. At baseline (fall 2009) and follow-ups, the Art2STEM girls reported relatively high levels of achievement self-efficacy and attitudes related to STEM subjects and topics. Generally, there were few changes over time in these areas. Further, the data suggest more favorable attitudes towards science, engineering, and math than for technology. In fact, there is some indication that girls' interest in technology decreased over time. In spring and summer, girls reported less interest in knowing more about computers than was reported in the fall, and more often reported that visiting a factory was boring. Finally, the girls reported greater interest in pursuing careers in science and engineering in the spring and summer relative to fall. Thus, interest in studying these subjects in college may correlate with increased understanding of STEM careers.

The DAET results suggest that girls more easily and accurately described what engineers do in writing than in their drawings. In the larger core student sample, girls' written descriptions showed positive changes over time, specifically including fewer references to fixing or making things. In contrast, the girls' drawings in spring 2010 tended to more often reflect concepts of fixing relative to their fall 2009 drawings. In contrast, the sample of campers demonstrated a shift between spring and summer. Girls drew significantly fewer engineers fixing and building things and more engineers designing, creating, and inventing. A few girls depicted concepts such as programming and quality engineering during the summer 2010 DAET administration. Girls also drew significantly fewer vehicles and included more design tools (e.g., software and blueprints) in their summer 2010 drawings.

6. Conclusions

While this ITEST strategy award is currently in its second year, there are many positive indicators in each implementation strategy of the project[9]. Evaluation results show increased percentages in girls' perception on the STEM career objectives. Feedback received from the students, coaches and industrial partners are considered by the project implementation team for Art2STEM's continuous improvement. The key deliverables of the project in each middle and high school club are closely monitored and, any corrective action, if needed, is taken immediately. Future goals of this initiative include developing a sustainability model for the ongoing operation of its after-school clubs and summer camps and more tightly integrating its programs into middle to high school transition strategies and into 9th grade curriculum and activities preparing students for their choice of academies.

Acknowledgements

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