

The University of Central Florida STEAM Program

Where Engineering Education and Art Meet

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Abstract - ICubed is a National Science Foundation (NSF) funded project housed at the University of Central Florida aimed at increasing participation in STEM fields through coordination and institutional integration. The University of Central Florida Science, Technology, Engineering, Arts and Mathematics (UCF STEAM) is a component of ICubed. As a part of this program, UCF STEM faculty and undergraduate researchers work collaboratively with faculty and students in the College of Arts and Humanities to create science-inspired art based on the STEM researcher's explanations of scientific concepts and possibilities. Since the program's inception in 2010, over 700 University of Central Florida faculty and students have participated in the STEAM program with a large majority coming from engineering fields. An evaluation of the program over the last six years demonstrates that by encouraging strong post-secondary cross-disciplinary collaborations, the UCF STEAM program has enlightened UCF's undergraduate engineering students in a manner that not only leads to greater recognition of the interdependencies of right- and left-brain directed skills but also has helped to improve learning and communication skills.

This paper highlights UCF engineering STEAM activities and lends a discussion to the educational impact of such a program.

Keywords—(engineering education, art education, STEM, STEAM)

I. INTRODUCTION

The importance of science and math literacy is acknowledged globally (Seymour, 2002); however, America continues to be confronted with a crucial achievement breach in the Science, Technology, Engineering, and Mathematics (STEM) fields. In order to advance interest in these fields nationally, as well as keep up with competition abroad, it is

necessary to improve upon and revitalize STEM objectives in our educational institutions (NSB, 2007). Furthermore, the general public does not have an accurate understanding of STEM professionals and researchers and the work that they achieve (NSB, 2007; Reinhart et al, 2005).

Although historically the arts and sciences have been detached and categorized into a dichotomy of separate skill sets and ability, modern research, as well as societal discourse has led to a recognition of the advantages of integrating science and art in education and the “possibility this can improve upon and create a richer and more appropriate learning experience for students” (Swan et al., 2015).

STEAM has permeated the education scene from pre-school (e.g., Wolfrap, <http://www.wolfrap.org/education/institute-for-early-learning-through-the-arts/impact.aspx>), through K-12 (e.g., the artscience prize, <http://www.artscienceprize.org/asp/>), and post-secondary education. Multiple states are investing in STEAM programs as well as federal agencies including the National Science Foundation and the US Department of Education (Robelen, 2011). An on-line, open access journal has emerged called *The STEAM Journal* which defines STEAM main themes as “fostering innovation, the need for twenty-first century skills, and divergent and convergent thinking” (<http://scholarship.claremont.edu/steam/>).

The UCFSTEAM program joins a large number of university-level examples that have developed over the past decade. Performamatics was offered at the University of Massachusetts Lowell to computer science and music students (Ruthmann et al, 2010). It was found to attract students to STEM while reinforcing computer science concepts through music applications. James Madison University offered an undergraduate honors program capstone project course that brought together design and technology students (Radziwill et al, 2015). They provide a conceptual model of STEAM

learning based on this experience. A leader in the field of STEAM at the university level is the Rochester Institute of Technology (Vullo et al., 2014). RIT has multiple examples of integrating art and technology including game design, general education, and a Jetsons flying car challenge. Vullo et al. observed that separation of creativity and understanding across multiple units “limits the conversations needed for exploring and developing new and improved art and technologies.” It was in this spirit that UCFSTEAM was pursued.

II. UCF ICUBED

The Project entitled Innovation through Institutional Integration: UCF Embraces the Knowledge Based Economy (Icubed) (No. 0963146) is funded by the National Science Foundation’s (NSF) Innovation through an Institutional Integration (I³) program. ICubed partners with several units within the University of Central Florida (UCF) including the College of Engineering and Computer Science (CECS), the School of Visual Arts and Design (SVAD), the College of Education and Human Performance (CEDHP), the Office of Research and Commercialization (ORC), and the College of Sciences (COS). The project received a five-year continuing award in the amount of \$1,045,130 in May 2010. The goal of this project is to ensure broader impact of NSF-funded projects through coordination and integration of educational research aimed at increasing participation in science, technology, engineering, and mathematics (STEM) fields. Since the program started in 2010, over 700 University of Central Florida faculty and students have participated in the ICubed program and over 50,000 members of the general public have been impacted by ICubed in some way.



Figure 1. Pictures from the Annual UCF STEAM Exhibition

III. UCF STEAM

University of Central Florida Science, Technology, Engineering, Art and Mathematics (UCF STEAM) is a

component of Icubed. There are four primary goals for UCF STEAM:

- 1 encourage new collaborations among university researchers,
- 2 inform and entice students to become part of creative projects that involve the STEM disciplines,
- 3 enlighten the public in a manner that leads to greater recognition of the interdependencies of STEM in their daily lives, and
- 4 assist students and faculty members to become better ambassadors to the public and their colleagues from other disciplines.

A. STEAM Organization

As a part of this program, UCF STEM faculty and undergraduate researchers, who have received ICubed Research Experience for Undergraduates (REU) stipends for their participation in the program, collaborate and interact with faculty and students in the College of Arts and Humanities (CAH). Participating CAH students, as part of their course of study, create science-inspired art based on the STEM researcher’s explanations of scientific concepts and possibilities. CAH and STEM students and faculty interact over a three-week long period. To date, classes in sculpture, painting, illustration, photography, music composition, graphic design, and print making have been included. STEM participants have included faculty and students from Engineering, Physics, Computer Science, Biology, Chemistry, and Biomolecular Sciences.

UCF STEAM encourages STEM researchers to expand their thinking and develop high-concept, high-touch senses that are needed today. The program provides pieces that challenge viewers to interpret science-inspired artworks through visual metaphor (Poindexter, 2013). More information on UCF STEAM can be found at Icubed.ucf.edu.

B. UCF STEAM Exhibition

Each year, ICubed hosts an exhibition to showcase resulting artwork from UCF STEAM collaborations campus wide. More than a thousand visitors have enjoyed this annual exhibition since the project’s inception and over 500 pieces of art have been produced and shown. These artworks have included paintings, prints, photographs, 3D multimedia art, musical compositions, sculptures, and drawings. Additionally, program participants have worked to create over 100 science-inspired graphic design posters, many of which are also showcased in the annual STEAM Exhibition. ICubed evaluative efforts have shown that the STEAM gallery has been successful in bringing artists, scientists, and the general public together for an event they enjoy and has served as a catalyst for cross-disciplinary collaboration. Pictures from the STEAM Exhibition Showcase can be seen in Figure 1.

IV. UCF STEAM ENGINEERING

Of the 43 STEAM seminars sponsored by ICubed over the years, many of the topics have consisted of engineering research and concepts. Mechanical, Aerospace, Electrical

Industrial, Environmental, and Civil Engineering researchers have all been involved in STEAM seminars in some capacity.

A. Examples of Engineering STEAM Seminars

Examples include the following:

- In 2011, Debra Reinhart, Ph.D., Professor, UCF Department of Civil, Environmental, and Construction Engineering, and ICubed Co-PI, along with an undergraduate researcher and doctoral student, also from environmental engineering, presented a lecture on nanoparticles to a UCF sculpture class. Reinhart and her team discussed their research on the environmental implications of nanoparticles specifically in landfills.
- In 2014, Yier Jin, Ph.D., Assistant Professor, UCF Department of Electrical Engineering along with an undergraduate computer sciences student presented on cybersecurity to an advanced painting class. Students learned about the susceptibility of information theft in the digital age and about barriers to appropriate security online.
- In Spring 2015, Subith Vasu, Ph. D., Professor, UCF Department of Mechanical and Aerospace engineering along with his undergraduate engineering researcher, gave a presentation on laser diagnostics and sensors to a UCF drawing class. Students learned about how lasers are used to measure gaseous species in different environments.
- In Fall 2015, Dr. Reinhart and an Industrial Engineering student gave a presentation on food waste to a UCF photography class. Students learned about the Food, Energy, Water nexus as well as innovations to prevent waste of food and energy.
- In Fall 2015, Kevin Mackey, Ph.D., Professor, UCF Department of Civil Engineering, along with his undergraduate engineering researcher, gave a presentation on the structural integrity of bridges to a UCF advanced painting class. Students learned about how civil engineers study and measure Earth's natural movements to design site specific structures using stress and function appropriate materials and methods.



Figure 2. Images of STEAM sculptures inspired by Dr. Debra Reinhart's 2011 presentation on the effects of nanoparticles on the environment.

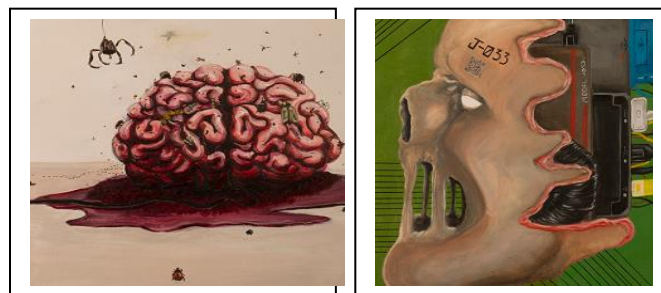


Figure 3. Images of STEAM Paintings inspired by Dr. Yier Jin's 2014 presentation on Cybersecurity



Figure 4. Images of STEAM Photographs inspired by Dr. Reinhart's 2015 presentation on Food Waste

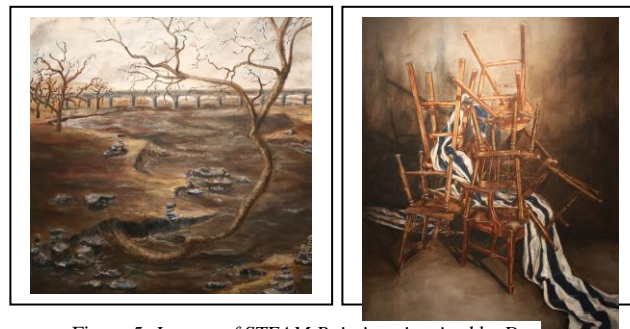


Figure 5. Images of STEAM Paintings inspired by Dr. Mackie's 2015 presentation on Structural Integrity

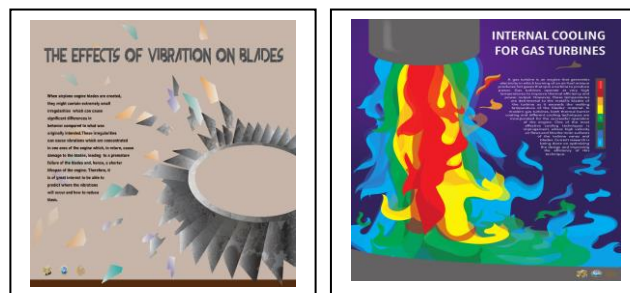


Figure 6. Images of Spring 2016 Graphic Design STEAM Engineering Posters.

In all of the examples listed above, UCF College of Arts and Humanities students responded visually and intellectually to these topics while and exploring how science affects their daily lives. Examples of artwork and posters inspired by these STEAM seminars can be seen in Figures 2-6.

B. Interdisciplinary Collaboration

Intertwining art with engineering research through the annual STEAM Gallery and semester-based STEAM seminars is being explored as an avenue to both enhance comprehension in STEM for non-STEM enthusiasts and boost the abilities of engineers to create new concepts and innovative ideas and to communicate these ideas to the general public. By participating in STEAM activities, students in their respective disciplines can gain a deeper understanding of their content area and become engaged with new material in a more meaningful way (Garoian & Mathews, 1996). The STEAM initiative challenges the notion that the arts and sciences are rigid disciplines and encourages integration of knowledge and skills across fields.

“At the highest levels of innovative thought, art and science share a common goal: the investigation of reality, beginning with observation” (Poindexter, 2013). Although artists communicate through artistic metaphor and engineers communicate through logical reasoning, both fields aim to produce innovative and creative problem solving skills within their disciplines.

The initial goal of the UCF STEAM project aimed to help STEM researchers better communicate their ideas through creative visualization and develop new ways to present complex scientific ideas to non-STEM audiences. The program quickly expanded as formal presentations evolved into a more casual sharing of information and ideas. Creative collaborations between participants from both disciplines began to naturally occur and competition to find the most compelling way to communicate concepts through words and images became the shared goal. Eventually, artworks were produced that did not merely illustrate scientific applications but also created discourse between participants and viewers at annual showcases and exhibitions.

C. The Creative Process

The processes involved in creative discovery for an art student are not unlike the methods pursued in basic scientific research. An artist begins by formulating questions based on intuition and knowledge of the subject and then tests and retests until a suitable, personally relevant solution – their finished artwork – is found. This mostly private undertaking is followed by public scrutiny in the form of a group critique of the work by instructors and peers, which when effective, leads to the essential skill of self-criticality and eventually, a creative outcome.

STEM students report that they have discovered new ways to explain scientific ideas to non-science students and acknowledge the benefits of these skills to their future careers as educators and applied scientists. In response to his collaborative work with art students, one STEM student also recognized his new appreciation for art. “Since I’ve been involved with this STEAM project, I’ve seen more art than I’ve ever looked at before, I respond to paintings like I never did. I had only been around math and physics and that style of training. Now I’ve seen what bending the universe looks like.” (Frye, 2013)

V. EDUCATIONAL IMPACT

An evaluation of the program over the past five years demonstrates that by encouraging strong post-secondary cross-disciplinary collaborations, the UCF STEAM program has enlightened UCF’s community in a manner that leads to greater recognition of the interdependencies of right- and left-brain directed skills. The incorporation of art in the curriculum with engineering fields assists students in their communication skills, problem solving skills, and self-esteem (Brewer, 2002).

A. STEAM Assessment

The ICubed project is tracked annually using an outcome oriented evaluation process. It features a mixed-method design with a standards-based (Yarbrough et al. 2011) and client-centered/responsive approaches (Stake, 1975, 1980, 2004; Stufflebeam, 2001). Each reporting period, data are gathered from multiple sources using several techniques, including surveys administered to STEM and Art students as well as interviews conducted with STEM and CAH faculty/instructors. Descriptive statistics were applied to survey data and interviews were audio taped and later transcribed. Responses from the transcripts and open-ended survey responses were summarized, and when possible, themes were identified based on emerging topics (Krueger, 1998; Miles & Huberman, 1994). A sample of UCF STEAM survey results, provided by the UCF Program Evaluation and Educational Research Group’s (PEER) 2015 ICubed Evaluative Report, are highlighted below.

1) STEM Students’ STEAM Survey Results

For the involved STEM student researchers, 100% reported having shared their STEAM experience with others. Results revealed that all (100 %) agreed that participation in STEAM improved their ability to explain their research to a non-technical audience. Also, all (100%) reported that their time-management skills had improved and their leadership skills had been sharpened due to their involvement. Finally, STEM students reflected on the benefits of such a program. Overall, they perceived STEAM as a positive experience and enjoyed being exposed to multiple perspectives. Some quotes from the 2015 STEM student survey are provided below

- “[STEAM] helped me learn how to relate to a completely different field in ways that allowed me to not only have the students involved understand advanced research concepts, but also allowed myself to better simplify many of the complex aspects of my research.”
- “[STEAM] opened my eyes to the usefulness of art to elicit change in the world, as well as its ability to shift the world's focus to important topics relayed by the STEM disciplines.”
- “Explaining your work to an artist really helps you learn how to word your project in a way the public can understand.”

2) Art Students' STEAM Survey Results

Art students' reflections revealed that a large majority were satisfied throughout the process. Approximately 63% of art students completed the survey; of the respondents 86% believed that the researchers explained their research well and answered questions effectively, and 86% reported the researchers helped them further understand the scientific concepts. A majority reported a positive change in their perspectives of STEM disciplines: 52% agreed that participating in this project changed their view of STEM and 48% indicated that they are now more curious about how STEM affects their lives. See Figure 7. Samples quotes from the 2015 Art Student STEAM survey are provided below.

- "I believe we have achieved something special. While it is hard for (some) musicians to understand anything but the simpler math, collaborating on a unique theme is a good experience."
- "This project has provided an interesting opportunity to align our interests and skills in the arts with those of our colleagues in [STEM]."
- "It's interesting to get a project like this with such interesting parameters. I think it's a great way to get people to think outside of the box."

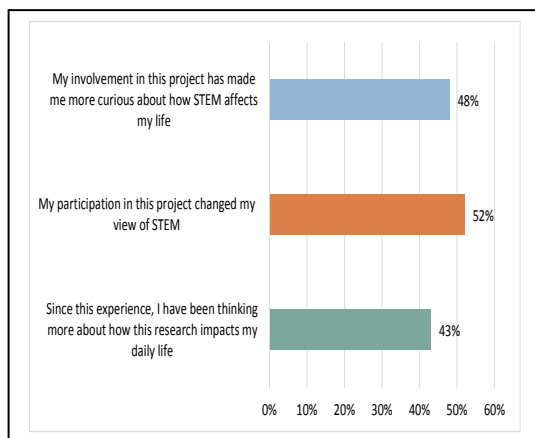


Figure 7. Student Perceptions for Overall Impact of the STEAM Seminars

VII. COMMUNITY IMPACT

The UCF STEAM program has implications that reach far beyond those experienced in a traditional classroom setting. In fact, program efforts have impacted the UCF, Orlando and national communities on a considerable scale. Highlights of UCF STEAM activities and their public significance are provided below.

A. *Fusion: A STEAM Gallery*

"Fusion: A STEAM Gallery" is a new educational partnership between UCF and the Orlando Science Center (OSC) and was created in an effort to increase the Orlando community's

accessibility to STEAM exhibitions. *Fusion* will serve as a permanent gallery space for science-inspired artworks and will exhibit four different science and art inspired shows each year. According to UCF Gallery Director, Yulia Tikhonova "Both UCF and OSC play key roles in creating the next generation of STEM professionals – UCF in higher education and OSC through youth engagement in hands-on science, technology and engineering activities." This gallery will help achieve the UCF STEAM goal of informing the greater UCF community about STEM professions, research, and concepts.

B. *Otronicon at the Orlando Science Center*

In addition to the exhibitions in the Fusion Gallery, OSC has showcased UCF STEAM artwork during their annual Otronicon conventions. Otronicon highlights Orlando's interactive technology resources and features larger-than-life video game experiences, state-of-the-art medical and military simulations, and game design workshops taught by industry professionals. Selected STEAM artwork has been exhibited during this convention and over 20,000 guests visit OSC for the Otronicon events each year.

C. *UCF Celebrates the Arts*

UCF Celebrates the Arts is a weeklong festival that recognizes and celebrates Central Florida's Performance and Visual Arts. The seven days of performances and activities include productions in Theatre, Orchestra, Opera, Dance, Visual Arts, Bands, Interactive Gaming, Chamber Music, Cabaret and Choirs. The ICubed program has co-sponsored two productions in conjunction with this event, one in April 2015 entitled *Icarus at the Edge of Time*, an interactive musical and visual performance featuring physicist Brian Greene and actress Kate Mulgrew and one in April 2016 entitled *Interstellar: The Warped Side of the Universe*, a multimedia concert event featuring composer, Hans Zimmer; visual artist, Paul Franklin and physicist, Kip Thorne, the creative minds behind the 2014 film, *Interstellar*. It is estimated that over 4,000 people attended these events including UCF faculty, staff and students, students in grades K-12, and members of the greater UCF community.

D. *UCF CREATE*

The UCF Center for Research and Education in Arts, Technology, and Entertainment (CREATE), under the direction of Stella Sung, conducts multidisciplinary STEAM projects, and research-driven initiatives, as a part of the University of Central Florida. CREATE's affiliated faculty, students, and staff explore a myriad of educational, research, and creative topics while promoting community awareness among students in grades K-5. Many of the artworks produced by the CREATE partnership have been showcased in ICubed's annual STEAM gallery.

E. STEM Day

ICubed partnered with the UCF Center for iSTEM (initiatives in STEM), led by ICubed project team member, Dr. Melissa Dagley, to host two biannual UCF STEM Days. These free events, co-sponsored by the National Science Foundation and Astronaut Science Foundation, showcase UCF's STEM and STEAM resources to the greater Orlando community through a wide variety of engaging activities designed for K-12 students. It is estimated that about 4,000 K-12 students were served each STEM Day. Regional elementary and middle school students visited the UCF University gallery for demonstrations and artist talks on science inspired art.

In addition to the activities highlighted above, the UCF STEAM program has made a push to gear its efforts towards a focus on public art. The UCF STEAM collection of science inspired artwork brings art to the UCF campus as well as the community. The 2016 Barbara Goldstein and Associates, UCF Public Art Master Plan, Preliminary Report states that,

“The University's campus, while relatively young, has a strong visual identity built on concentric circles and their reinforcing landscape elements, and this identity will become even more striking as the landscape matures. Public art can be a more intentional part of that visual identity with careful placement that helps to orient campus visitors and students, punctuate specific zones of the campus and creating a unique sense of place. As the University expands to its downtown Creative Village, art can help define the visual identity of that precinct of Downtown Orlando as well. The timing for developing a public art strategy is excellent.”

Currently, student donated UCF STEAM artworks in the University's public collection brings art to public spaces throughout the university including year-long exhibitions in the UCF Student Union Circle Gallery, the annual STEAM Exhibition, and more. A summary of these exhibitions is provided below.

EXHIBITIONS:

- (2011) *The STEAM Exhibition*, University of Central Florida STEM Conference (180 attendees)
- (2012) *The STEAM Exhibition*, UCF Gallery (400+ attendees)
- (2012) *STEAM: Searching for Ultimate Truth in Science and Art*, UCF's Center for Emerging Media, Gallery 500 (280 attendees),
- (2012) *PhysCon: Quadrennial Physics Congress: Art Contest* (700 attendees)
- (2013) *Otronicon STEAM Exhibition*, Orlando Science Center (7000 attendees)
- (2013) *The STEAM Exhibition*, UCF Gallery (500+ attendees)
- (2014) *UCF STEAM Exhibition*, UCF Gallery (500+ attendees),

- (2014) *UCF STEAM Exhibition – Where Art Meets Science*, UCF Student Union Circle Gallery.
- (2015) *UCF STEAM Exhibition*, UCF Gallery, (500+ attendees)
- (2015) *UCF STEAM Graphic Design*, Orlando Public Library
- (2016) *UCF STEAM Exhibition – Where Art and Science Meet*, UCF Gallery, included artworks created by 4th and 5th grade students through the UCF CREATE Program under the supervision and direction of Tracey Morrison.

Future goals for UCF STEAM includes planning, proposing and creating science inspired public art for UCF's main campus and newly approved downtown UCF campus, a UCF Study Abroad Program to Greece for Science and Art students in Summer 2017, continuing science-inspired assignments in Art classrooms at UCF, and identifying and implementing new opportunities for science and art collaborative activities for UCF students and regional K-12 programs.

VIII. CONCLUSION

The concept of STEAM capitalizes on the principle that science and can be applied in conjunction to explore, investigate, and produce in everyday life. The UCF STEAM program combines these disciplines in educational settings that enhance student scholarship. The integration of art with science concepts enhances student learning within all fields through facilitating development of critical thinking skills, transference, and heightened motivation. Furthermore, the incorporation of art within engineering curriculum assists Engineering students with their communication skills, problem solving skills, and self-esteem. Expansion of STEAM programs and curricula could help produce more cultivated and well-rounded engineering and art students who are able to engage in creative problem solving and explore new possibilities to respond to some of the world's greatest problems.

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