A Pipeline of High Achievers to STEM Program

Dr. Ravi T. Shankar, Florida Atlantic University

Ravi Shankar has a PhD in Electrical and Computer Engineering from the University of Wisconsin, Madison, WI, and an MBA from Florida Atlantic University, Boca Raton, FL. He is currently a senior professor with the Computer and Electrical Engineering and Computer Science department at Florida Atlantic University. His current research interests are on K-12 education, engineering learning theories, and education data mining. He has been well funded by the high tech industry over the years. He has 7 US patents, of which 3 have been commercialized by the university. This research work is a collaboration with the Children's Services Council of Broward county in FL.

Mr. Francis Xavier McAfee, Florida Atlantic University

Francis X. McAfee, Associate Professor in the School of Communication & Multimedia Studies at Florida Atlantic University (FAU) merges his background as a ceramic sculptor and printmaker with new digital technologies. After graduating with a BFA in Art in 1989 he joined the Florida Center for Electronic Communication (CEC) as a lead artist creating animation for applied research projects. These computer animated films were nationally and internationally screened in New York, Chicago, Hollywood, San Francisco, and Tokyo in industry recognized competitions as the International Video Art Competition, the New York Festivals, and the American Film Institute.

McAfee is also active in web-based virtual reality projects. His research includes digital archaeology of a deteriorating ancient tomb in Sicily to help preserve and visualize its' characteristics for future study. His collaboration with Florida International University's International Hurricane Research Center showed how certain roof construction materials may become projectiles during high wind events. For the FAU Center for Environmental Studies' Sea Level Rise Summit McAfee lead a student team to produce a short animated video showing what might happen to the neighborhood around the Miami Freedom Tower if sea level rises to its full potential impacts. The video was picked up by National Public Radio and other media outlets. In 2007 he helped visualize the research of FAU's Ocean Engineering using animation for a competition for a State of Florida Center of Excellence. FAU won the completion and has since been named as a national research center, Southeast Regional Marine Renewable Energy Center. Since 2009 he has collaborated with colleagues in Computer Sciences and other colleges to form cross-disciplinary student teams that create software applications for Android mobile devices.

McAfee compliments his professional activities with volunteer service for ACM SIGGRAPH. He served on their executive committee as Director for International Chapters and has organized local Fort Lauderdale chapter events for over 20 years.

Dr. Diana Mitsova, Florida Atlantic University

Diana Mitsova has a background in research design, statistical and spatial analysis, as well as environmental planning and modeling using geographic information systems, and interactive computer simulation. Her primary area of research involves the impact of urban development on ecosystems and other environmentally sensitive areas.Her recent publications focus on the impact of climate-related stressors on coastal communities and the implementation of planning approaches related to enhancing coastal resilience to natural hazards. Her research has been funded by the National Science Foundation, National Park Service through FAU Environmental Sciences Everglades Fellowship Initiative, USGS, and The Nature Conservancy.

Mrs. Summer Scarlatelli, Museum of Discovery and Science

Summer Scarlatelli, STEM Center for Education and Career Development Manager , creates and conducts programs for school groups, grants, community outreach and camp-ins that introduce basic science concepts and enhance the STEM content of the exhibit experience. She coordinates with Broward Schools to ensure museum activities support Common Core standards. She is currently working with United Way

of Broward County and Florida Atlantic University engaging high school students in mobile app development and the Community Foundation on an afterschool program for low performing middle school students. Ms. Scarlatelli has a Master's degree in Environmental Education from Florida Atlantic University. Previous experience includes the Miami Seaquarium and 5 years as a K-12 science teacher at Fort Lauderdale Preparatory School.

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Abstract:

This paper documents our collaboration between a university and a science museum to help motivate high school students to attend engineering programs upon their graduation. With the aid of a grant, the museum recruited above-average local high school students for a two year internship program. There were an equal number of boys and girls, and the group was representative of our local multi-ethnic community with large underrepresented minorities. The students spent the first 9 months as interns at the museum, immersed in the activities and exhibits of the museum. They then attended a summer course on app development at the university. Students worked in teams to build an app pertinent to their museum exhibit of choice. Subsequent to that, they returned to the museum and improved the app based on their interactions with the museum visitors. Two groups of students have undergone this program so far. Our summative and formative evaluations and student self-assessments indicate significant knowledge gains in all team and technology skills emphasized in the course. Student also commented positively on their own personal growth in assignments submitted to the museum. Though we have not tracked them officially, we believe that most of the first year's graduates have joined STEM programs.

Background:

The demands of academic science, technology, engineering and mathematics (STEM) programs may dull students' enthusiasm and destroy their academic self-concept (ASC) and confidence. However, the popularity of science museums around the world is a notable testament to humans' enjoyment of scientific discovery. We provide here a process to invigorate the interest of America's talented students in science degrees via a community outreach program with one's local science museum.

We address this critical need to recruit students into STEM programs by (1) building robust affect-informed support for their knowledge construction during immersion experiences with a local science museum and (2) engaging them in teams in the development of smart phone applications relevant to science exhibits, in a formal course at a university.

We have recruited 66 above-average high school students over the past two years, thanks to a grant to our local science museum (MODS, or the Museum of Discovery and Science, Ft. Lauderdale, FL) by a major nonprofit organization (the United Way). This was called the 'APPtitude' program, a play of words on the two goals: app development and improvement of STEM attitudes. There were an equal number of boys and girls, and both groups were representative of our multi-ethnic demographics and large under-represented minorities. During the internship academic year, these students participated in an immersion experience at the science museum. They formed teams of 3 and focused on a specific exhibit and learned its' scientific, educational, and community relevance. These teams then developed an Android app for the exhibit, during a 3-week intensive summer course at our university (FAU, or the Florida Atlantic University, Boca Raton, FL). This course was co-taught by two professors one each from engineering and arts. A group of judges, comprised of professionals from the industry, academia, and community, evaluated the team presentations and ranked the apps based on a rubric. Students returned to the museum during the following year to improve the app, share it with visitors, and understand better the museum dynamics.

We have completed 2 years of this 3 year grant. During each of the summers, students were given pre-course and post-course questionnaires which measured learning outcomes for multiple attributes. Knowledge gains were assessed on a Likert scale from 1 to 5 where 5 indicated the highest level of self-reported improvement. The results indicate significant knowledge gains in all team and technology skills emphasized in the course. Student commented on their own personal growth using superlatives. During the 2nd year and the current 3rd year, we have sought to tease out the impact of the museum internship on the overall gains made. We hope to present the latter results at the conference.

Our approach is derived from two theoretical models with strong emphasis on student involvement in the learning process: active student engagement and project-based learning. Both approaches assume active student participation in learning practices where exchange of ideas, extensive collaboration, and synergies are essential.

The Smithsonian Institution recently suggested that mobile should be understood as social media and projects should leverage its ability to create conversations, communities, and collaborations. This requires a museum community that will share code, tools, and best practices with a reusability focus. We follow this philosophy. We use only open source tools and student apps are available for free access as Github repositories. A platform independent app development methodology has also been developed now, so the app can run on all smartphones.

Rationale:

Our local community is highly diverse with a large population of underrepresented minorities. This collaboration arose out of a desire to expose local youth to potential STEM careers that matched their interests, with an opportunity to build soft and hard skills needed to succeed. We review here the trends and literature that informed us on our approach.

A recent study from Rutgers University (Lowell et al., 2009) reveals that for students who scored in the top 20% on the SAT or ACT math test, recruitment rates to college STEM programs fell sharply from 28% in the 1990s to 14% in the 2000s (three-times the average for all the test takers). If this continued today, then the recruitment rate would be below 5%, the average for all the test takers. The retention rates for such STEM professionals at mid-career also declined over the same period. Without better recruitment and retention, the ranks of leaders and innovators in STEM fields may dwindle. Although the US continues to attract high achievers from abroad, the reverse brain drain will cause a vacuum in US leadership ranks. We estimate that 100,000 additional such high achieving graduates can graduate with STEM degrees, over the next few decades, by judiciously addressing their needs and frames of reference. This matches well with the call from the President's Council of Advisors on Science and Technology (PCAST, 2012) for one million additional college graduates with STEM degrees, and NSF's desire to educate students to be leaders and innovators (IUSE Webinar, 2013).

Previous research in Academic Self-Concepts (ASC) suggests that many high-achieving STEM students will benefit from the "small pond" experience at a "non-top 30" university (Marsh, et al., 2008). The corresponding theoretical premise is that perceptions of the self cannot be adequately understood if the role of frames of reference is ignored. ASC is considered to be a good predictor of future achievements. We combine here elements of informal and formal learning with near peer-to-peer mentoring, and creative problem solving, in a multidisciplinary environment, so 'above-average' achievers from our diverse community become aware of alternative, challenging, and/or lucrative STEM careers (Lowell et al., 2009), all the while being in a "small pond" which should positively impact the ASC. We put 'above-average' in quotes, since there is evidence, as noted below, that their Social Economy Status (SES) may have artificially depressed their normative scores.

Cultural diversity is both a reality and an opportunity. The US Census predicts that from now through 2060, the degree of diversity will increase with the White, Hispanic, and Black populations changing from the current ratio of 4:1:1 to 3:2:1 (Ortman, 2013), as the overall population grows about 33%. College Board (1999) found that only about 1 in 20 of the students with very high SAT1 scorers were from the underrepresented minorities. This implies a substantial reduction in high achievers, from 8.4 M to 7.4 M, as diversity increases. However, Turkheimer et al., (2003) have shown that the state of impoverishment is a detriment to high achievement. They determined the relationship between SES and student scores in Wechsler intelligence (IQ) tests. SES is a measure of the quality of the environment in which children were raised. They showed that in families with low SES scores, 60% of the variance in IQ of twins is accounted by the shared environments, and the contribution of the genes is close to zero; in affluent families, with high SES scores, the result is exactly the reverse. It is also a nonlinear relationship, with differences among poor environments contributing more to differences in phenotypic outcome than differences among better environments. This suggests that there are potential high achievers among the student population, even if SAT/ACT scores are not high.

We believe that these students will attain high ASC, if nurtured and stimulated appropriately, and have the potential to become well-informed and capable scientific leaders and innovators, and more importantly role models for the younger generations of their ethnicity, school, and county.

Our university (Florida Atlantic University) has an opportunity to be the "learning lab" for the multicultural society of today and tomorrow. With 53 percent of its student body classified as minority or international students, our university ranks as the most racially, ethnically and culturally diverse institution in our state university system. We are ranked high in the nation for bachelor's degrees conferred on minority students. Fry (2012) reports that in 2012, 36% of the nation's young adults were living in their parents' home, driven by a combination of economic, educational and cultural factors. Our university and local counties will be much more strongly connected in the decades to come, with a strong tilt to predominance by the Hispanic and Black residential student communities, with a low SES. However, it is clear that low SES does not necessarily have to lead to low achievement. There is potentially a significant number of High IQ students among the low SES group who fall below the radar of screening with the GPA and

SAT/ACT scores. Many more high IQ students can be recruited into the STEM programs and achieve higher ASC at our university. This Big-fish-little-pond effect (BFLPE) is likely to be more manifest in a second-tier university with a multicultural environment like ours (Marsh, et al., 2008) where their non-STEM impediments (such as the language, cultural and communication barriers) are less stressful.

Diversity is also an opportunity in a different sense. There is a great need for a diverse STEM workforce that can maximize a more global perspective for problem solving. Antonio et al (2004) have shown that students' complex thinking improves when they work in multicultural groups (from exposure to diverse perspectives). This applies to both racial- and opinion-minority members. Our alliance harnesses that at multiple levels in our program. The recruited students spend nine months working in teams at the local science museum and develop a consensus theme for the exhibit app that they develop the following summer at our university. They then present their app to museum visitors during the following year and learn from that experience. This should help us build a stronger pipeline of high achievers at STEM.

Persisters and Non-Persisters in Engineering:

Recent push to increase enrollment, retention, and graduation of STEM graduates has led to many research studies to identify the characteristics of those who graduate in engineering ('persisters') and those who leave engineering majors ('non-persisters'). Matusovich et al., (2010) undertook to understand how and why students opted to enter and persist in engineering. Persistent rates of engineering students are similar to students in other disciplines; however, engineering has a gender gap, not seen in other disciplines. Thus, their study is all the more important to build a large and diverse community of engineers. They used motivation theory of Eccles, called expectancy-value theory to explain persistence. Eccles' theory factors in gender and ethnic differences in STEM participation (Eccles, 2005). They hypothesized that educational, vocational, and avocational choices would be most directly related to person's expectations for success and the value they attach to the available options. Simply put, the Eccles' theory suggests that choices to engage in activities are shaped by competence and value beliefs. Competence is about acquiring skills and applying them. Competence beliefs have been studied more widely than value beliefs among K-12 and engineering students. They are mostly based on the self-efficacy theory (Bandura, 1997). Self-efficacy is enhanced by positive feedback, better performance, and social comparisons. Value beliefs have not been that well studied. Whereas competency beliefs look at a person's ability to engage in an activity, value beliefs consider the desire and/or importance of engaging in the activity.

The value system refers to one's own personal importance for the task. Matusovich et al (2010) use Eccles' theory (2002 and 2005) to address the value system among engineering students: how do engineering students' engineering-related value beliefs contribute to their choices to engage and persist in earning engineering degrees? The Eccles' theory covers four value categories: interest, importance, cost, and attainment, to describe how individuals assign importance to engaging in an activity. Matusovich et al developed operational definitions for the value categories as follows: Attainment refers to a reason for pursuing (or not) engineering that is related to the self-perceived identify of an engineer; Cost is the price of success (or failure) in terms of effort, time, and/or psychological impacts in pursuing engineering in comparison to another career; Interest is the enjoyment (or lack of) experienced in doing engineering activities; and Utility is the perceived usefulness (or lack of) of becoming an engineer and/or earning an engineering degree (Matusovich et al., 2010). The authors conducted longitudinal semi-structured interviews of 11 participants (5 boys and 6 girls) during their four years of undergraduate engineering education. They found that all four Eccles' value categories were present; that attainment value plays a prominent role, but not an exclusive role, in participant's choice to earn an engineering degree; and that the four categories are not mutually exclusive. In summary, the researchers found that participants can be categorized with high or low engineering-related attainment values. Participants with high attainment values have low cost values, moderate to high interest values, and moderate utility values. Participants with low attainment values tend to have moderate or high cost values, low or moderate interest values, and moderate or high utility values. The one student who left the engineering program and opted for the teaching profession had low attainment value. Though the study is inconclusive on persistence (due to the small sample size), the study suggest a need to increase students' attainment values related to engineering in order to increase persistence. That is, "we can encourage students to stay in engineering by helping them associate a perceived engineering identity with their personal identity and demonstrating the value of this association." Further, lower attainment values are seen among women along with greater uncertainty about engineering and engineering abilities found in them, despite their higher grades and persistence; this suggests it is very important to develop interest and competence beliefs in women to recruit and retain them in engineering fields. We are not aware of any similar study that focused on specifically the under-represented minorities.

Our approach documented here uses both informal and formal learning processes in a seamless manner to facilitate this. For the informal component, we refer to a publication, "Identifying and Supporting Productive STEM programs in Out-of-School Settings" (National Research Council, 2015). They suggest the following three criteria to facilitate this: (1) Engage Young People Intellectually, Academically, Socially, and Emotionally; (2) Respond to Young People's Interests, Experiences, and Cultural Practices; and (3) Connect STEM Learning in Out-of-School, School, Home and Other Settings. Our museum part of the experience brought together students from across a large county, typically no more than a few students from a given high school, to meet, interact, learn, and plan an app that is personally appealing to them and using that as the backbone for their app development at our university.

In an earlier publication from the National Research Council (2009), entitled "Learning Science in Informal Environments: People, Places, and Pursuits," the authors conclude as given below (next paragraph). We present also brief comments in parentheses. These comments show how well our integration of the informal museum component, the formal app development component, and the students' individual values, matches well with the authors' conclusions and recommendations:

- About Learners and Learning: (1) Individuals learn about the natural world and develop important skills for science learning, across their entire life span; (2) A great deal of science learning takes place outside school in informal environments, including everyday activity, designed spaces (such as museums), and programs (such as our museum internships); (3) Learning science in informal environments involves developing science related attitudes, emotions, and identities. Informal environments can be particularly important in this endeavor (The exhibit chosen for app development is of interest to the team); (4) Learning experiences are shaped by their cultural-historical backgrounds. This reflects a diversity of perspectives that should be recognized in designing science learning experiences (The exhibit's content has a personal connection); (5) Learners' prior knowledge, interest, and identity are especially important in informal environments.

- About Informal Environments: (1) Though composed of multiple communities of practice (Our student body is diverse in ethnicity, gender, economic status, geographical location), the environment must engage participants in multiple ways, encourage their interaction with natural and designed phenomena in a learner-centric manner, and build on learners' prior knowledge and interests; (2) Broadcast, print, and digital media can play an important role in facilitating science learning across settings (Student groups included in their apps the following: behind-the-scene interviews, video footage of exhibits, and augmented reality); (3) Science must be portrayed as a social, lived experience, by relating to contexts relevant to learners (Students chose an exhibit of their own liking); (4) Informal learning environments can have a significant impact on science learning outcomes of individuals from non-dominant groups who are historically underrepresented in science (Our student groups are highly diversified with strong representation from many under-represented minorities, a reflection of our diverse population); (5) Partnerships between science-rich institutions and local communities show great promise for fostering inclusive science learning. Developing productive partnerships requires considerable time and energy (Our collaboration between a university and a museum).
- Promoting Learning: (1) Parents, adult caregivers, peers, educators, facilitators, and mentors play critical roles in supporting science learning (Parents participated at events at both the museum and the university); (2) Programs for school-age children and youth in a growing phenomenon in which an increasing emphasis is placed on science.
- Informal Environments and K-12 Schools: (1) At present, there are no good outcome measures for assessing the science learning goals of informal settings. Conventional academic achievement measures are too narrow and not well aligned to the goals of informal providers (We use formative, summative and survey instruments in our evaluation).
- Toward a Common Field: (1) Quality of the research is uneven, at least in part due to limited publication outlets; (2) evaluation reports on particular programs provide an important source of evidence to inform practice and theory; (3) There is an interdisciplinary community of scholars and educators who wish to develop a coherent theory. However, more widely shared language, learning theories, and standards of evidence are needed to build a more useful knowledge base (We are contributing to this via research studies and app repositories. See Donate et al., 2015 and MODS (2015 and 2016); and (4) Ecological perspectives on informal environments can facilitate important insights about science learning experiences across venues (Both partners have collaborated to achieve research uniformity across both the environments; we are coordinating better in this 3rd year).

Research Design:

The main goal of this study is to understand how interdisciplinary instruction affects students' ability to identify, formulate, and solve problems, function on multidisciplinary teams, engage with contemporary issues, communicate effectively in writing, verbally and visually, develop appreciation of the impact of planning and engineering solutions in a variety of societal contexts, and develop understanding of their professional and ethical responsibilities. Soft skills, such as communication, team spirit, leadership, sociability, time management, documentation, presentation, ethics, negotiation, etc., are all critical in successful delivery of a standout App.

We also wish to test the hypothesis of a relationship between students' knowledge construction experiences and their STEM recruitment and retention rates. Research suggests that assessment and more specifically formative assessment where well-structured and sensitive feedback is provided to students can increase their self-belief and subsequently improve retention rates (Rust, 2002). Increased academic performance and competence (Tinto 1993, 2006) and "learning effects" (Prussia and Weis 2004) are found to improve student confidence and integration in the academic environment thus reducing attrition tendencies. We use improved student learning outcomes as evidence of student success affect retention rates.

Research Questions asked:

1a. Obtain feedback on student knowledge gains from cross-college instruction and the overall pedagogical approach

Pre-evaluation test administered at the beginning of the each course involved in cross-college pedagogy and post-evaluation test at the end of the three-week period. Note: 'Cross-college' here implies not only instruction by the engineering and multi-media professors, but also the effect of informal learning at the museum and interaction with the science and administrative leads there.

1b. Assess how well the pedagogical approach and assignment structure meet the specified cross-college learning objectives

This is based on subjective and objective analysis of student comments, assignment submission, student scores, and overall team performance. Student records, as available at our App management system (AMS), will be used in this analysis. Currently, the AMS is made up of Github for app repository and discussion wikis Github/Blackboard/Canvas. Frequency and quality of updates will help us understand better both the technical and soft skill improvements that we hypothesize will be achieved. For the purpose of this paper, students' uploads and comments have been tracked manually, with the intent to help, as appropriate.

2. Identify course elements that contribute to perceived student knowledge and soft skill gains and course elements that are perceived as ineffective and in need of improvement.

The intent is to determine which assignments helped students master discipline specific knowledge and which ones impeded this process. A low average score would indicate that the sub-objective was not met. If so, the material could be repeated in the class and/or aided with extra online classes, to ensure that the students will be fully prepared when they start the team interactions. This will ensure that the teams will not be disadvantaged due to discipline specific deficiencies.

3. Obtain feedback on student knowledge gains from instruction and identify course elements that contribute to perceived student knowledge and soft skill gains and elements that are perceived as ineffective and in need of improvement

This self-assessment instrument contains 17 questions, grouped in six sections, such as "programming," "critical thinking," "app elements," "problem solving," "user-oriented," and "design & presentation." Students are instructed to respond to the instrument questions on a five-point Likert scale. Students' evaluative statements (i.e., "response categories") are ranked from low to high where 1 point indicates a low perceived value in assisting their learning while 5 indicates high value in terms of knowledge gains.

Logistics and Teaching Pedagogy:

Student Recruitment Process: High school students in our county (Broward County, FL) entering their junior year in August are invited to apply for a two-year internship that "will provide an opportunity to earn volunteer service hours, college credit, and a stipend while advancing their knowledge in STEM education."

They are provided with the following information (the year value is specified below to convey the time sequence): The program begins in the Fall 2016 and runs through two years at the Museum of Discovery and Science (MODS). Students will meet at MODS a minimum of two times per month and also participate in local university's three week, dual-enrollment course during the first Summer 2017 at Florida Atlantic University (FAU). Upon successful completion of this college level course, students will receive three semester hours of college credit from FAU.

Qualifications to Apply: (1) Will enter their Junior year of high school in August 2016; (2) Receive the approval of their high school Guidance Counselor and Science Teacher; (3) Complete a profile survey on-line; (4) PSAT 88 combined in Reading and Math; (5) Have and maintain a 3.0 unweighted cumulative high school G.P.A; and (6) Before March 1, 2017 take the ACT, SAT, Accuplacer or P.E.R.T. and achieve all of the minimum scores on any one test (listed below.). Test Reading/Verbal Writing/English/Mathematics/Algebra S.A.T. 440 440 A.C.T. 19 17 19 Accuplacer 83 83 72 P.E.R.T. 106 103 114. These scores are slightly above 50% national percentile ranks.

Program Objectives: Increase skills in scientific disciplines; Increase awareness of STEM careers; Provide place-based informal learning; Advance youth in academic pursuits; Increase applied skills; Provide real-world, problem-based learning in STEM, and further interest in STEM and STEM careers.

Benefits of Completing Internship: College Credit; Dual Enrollment at FAU (Free tuition for public school system attendees with a GPA of 3 or better); Stipend ($300 after completion of the university course, August 7, 2016, and another $300 on June 30, 2017); and Volunteer Hours. Volunteer hours may be collected at the end of each school year. Roughly 60 to 80 hours will be required each year. This number includes all training sessions attended at the museum.

Added Benefits: Customer Service Skills; App development; Introduction to Computer Graphics; Business Skills; Team Building; Life Skills; and Life Long Friendships

Methods of Participation: One Saturday per month at the museum (10 AM to 4 PM); One weekday night per month at the museum – Meet and Greet with STEM industry leaders (5:30 PM to 7:30 PM); Invitations to special events; Homework assignments emailed to the coordinator; University class during the summer in July, MWF, 9.30 AM to 4.30 PM; and Workshops. All are mandatory.

Program Conduct:

Informal learning phase at the museum (MODS) is described above and is also captured in student comments provided below.

The three- week course at our university (FAU) follows a format that we have used in our regular semester long course for undergraduates, where typically students from engineering, digital arts, and a content area (such as urban planning, nursing, or public administration) have collaborated (Donate et al., 2015 and Shankar et al., 2017). It is compressed to a 3-week intensive program here. Briefly, all high school students are exposed to basic app development before being asked to self-select their role (Java programmer, UI designer, or Graphics designer) which is covered in concurrent sessions as appropriate. The teams of 3 are given an outline of the requirements and asked to create a story board which is presented to museum and university partners, as well as other student groups. Feedback and suggestions are incorporated in their refined version. Each team member develops their content as part of the class training in concurrent sessions. They then come together frequently in a common room to integrate the same, and they also iteratively improve (as a team) between classes. Undergraduate students in engineering and digital arts, serving as teaching assistants and near-peers, along with the faculty members (RS and FM, the first two co-authors) interact with all the groups individually, while providing more app examples to learn from. A second set of presentations on a semi-complete app are made at the end of the second week to make sure the apps are progressing well. The final presentations are held on the last Friday in the afternoon. A group of working professionals in engineering and multi-media, and the community leaders involved, judge the presentations based on a 10 item rubric. The top 4 teams are invited to make presentations at a local technology conference that is held semi-annually (MTC, 2008). It gives them an opportunity to network with local engineering managers, senior engineers, entrepreneurs, and business people. Pre and Post surveys are administered, as mentioned earlier. Student comments provided also include their perception on soft and hard skills attained at the university.

Results:

Informal Learning: Student assignments and testimonials:

The museum asked students and/or parents to submit short essays on three topics. We include two randomly selected comments from students or their parents for each of the three assignments.

(a) What part of the program has surprised you the most?

- “The part of this program that has surprised me the most is the friends I have made. I'm a relatively shy person and being in this program has exposed me to many people who share the similar interests. The extent to which with program requires me to interact and work with others has allowed me to break out of my shell and make good friends. These friends are just part of the reason why I enjoy being a part of this program. Volunteering at the museum and showing off our applications feels more like a privilege than a responsibility. It is a great way for me to learn from and interact with my peers. These are people who are living in my area, but I would have never met them if not for this program.”

- “When I was accepted into the Apptitude program, I knew that I would be creating an app for the museum. However, I did not expect to learn so much about the behind the scenes of the museum. For example, I did not expect to go behind the EcoScapes exhibit and see how all the aquariums are cared for. It was very interesting to learn about the amount of time and effort it takes to care for each tank. Also, I was surprised that I learned so much about myself during this internship. During the FAU class, I learned about how I handled stressful situations. Instead of getting frustrated, I’ve learned how to calm down and take everything step by step. The Apptitude program has helped me gain life skills that will be extremely useful in the workplace. In addition to learning how to deal with stressful situations I have learned customer service and communication skills. ”

(b) How has the program impacted you as a person?

- “One of the primary ways this program has impacted me as a person is by exposing me firsthand to the true college experience, essentially changing my outlook on my future and secondary education. Prior to this program I was apprehensive of my hastily approaching term in college, as I feared that it would simply be a second round of high school. I was worried that I would once again find myself feeling trapped, not genuinely enjoying my learning environment. My time at FAU during this internship eased these concerns, as I saw firsthand the flexible, diverse, and refreshing nature of university that I'm eager to immerse myself into. This program also changed me as a person by allowing to explore my passions in the field of STEM. I had always been interested in computer science, but until the internship was not presented with the opportunity to pursue these interests. This program has allowed me to enter the world of computer science, and has cemented my interest in coding and applications. One of the more unexpected ways that this program had changed me as a person is by giving me the opportunity to meet new people and make lifelong friends. When the internship first started I only knew one of my peers in the program, and we generally stuck to ourselves and avoided socializing. Now, however, I'm familiar with almost everyone in the program, and have formed close relationships with numerous participants that I've worked with or spent time with at FAU. We now message and communicate through social media on a regular basis, and meet in person as often as we can. A few of us are even attending the same university in the fall, which means that our friendships are guaranteed to last well into college.”

- “This program has definitely impacted me. Mostly, the impact has come from the FAU course, where we had to work fast and hard to get done what we needed, but the end results were well worth it. It was that time crunch that showed me what I was capable of doing when I put my mind and time into it, but also showed me how to do it, and that I actually really enjoy having a task, and getting it done to the best of my abilities. This idea will steer me in my future career. But far more than the FAU course, it was the people around me here at MODS that impacted me. Every time I go to volunteer on a Saturday, I see a new volunteer, both intern and not, that I haven't spoken with before, and we talk...and talk and talk, sometimes for hours. These interactions, this program, has helped me branch out from the shy, quiet girl I am into someone who is comfortable around other people. This definitely wasn't supposed to be the effect of this program, but to be with so many STEM-inspired, like minded, friendly people has had a hugely positive effect on me. Lastly, the teamwork. Unlike some groups, before November 2014 the Go Green team had never laid eyes upon each other. But to be able to come together, in such a relatively short time, to create a final product we are each beyond proud to call our own, was impactful. i had never teamworked on such a long-time scale before, nor had I ever come up with such a result. The teamwork has shown me what a team can do, and has helped me grow as a person."

(c) Provide an internship testimonial

- "Our son has grown so much in the last year and he really did enjoy this program. The applications he created really surprised me. I did not know he was capable of such expertise with coding and Android applications.

  I can't say enough about the APP-titude program at the Museum of Discovery and Science. Though his experience he has been exposed new coding techniques and has gained a deaper interest in the STEM Programs. I have seen his passion for computer science and coding blossom where he has taken it upon himself to learn additional computer applications towards possibly dual majoring in Engineering and Computer Science. This program has also helped Steven develop new friendships with other students across the ethnic spectrum of Broward County he never would have had the pleasure to meet.

  I highly recommend this program to any student with an interest to learn about STEM programs while giving back to their community."

- "I have had a great experience in the APPtitude program. Not only have I been able to learn about and better develop specific exhibits in MODS but I have also gained real world experience through the entire creation of my app. The APPtitude program gave me the ability to learn skills that I will use in college and in the real world, such as graphic design and user interface components. My stem abilities have been greatly advanced and I feel much more prepared for college."

Formal Learning:

We present here pre and post-survey results for both 2015 and 2016 teams. The surveys were conducted as per a protocol approved by FAU's institutional Review Board (IRB) for the Protection of Human Subjects. The protocol is current and is entitled as "Assessment for Learning Outcomes for Cross-College Instruction and Student Retention/Graduation."

There were 82 responses in 2015 (38 pre, and 44 post). In 2016, there were 62 responses (29 pre and 26 post). Note: There were only 33 students in each year's cohort. The inflated values for 2015 indicate partially completed surveys which got counted as full surveys. We have made adjustments for this.

The results from the students' self-assessment indicate that the students have gained knowledge in the areas of graphic design, text entry, and image capture. They also report better understanding of how to create "uniqueness" in their apps, and promote "educational use."

Figure 1 (a) and (b) exhibit the results from the analysis:

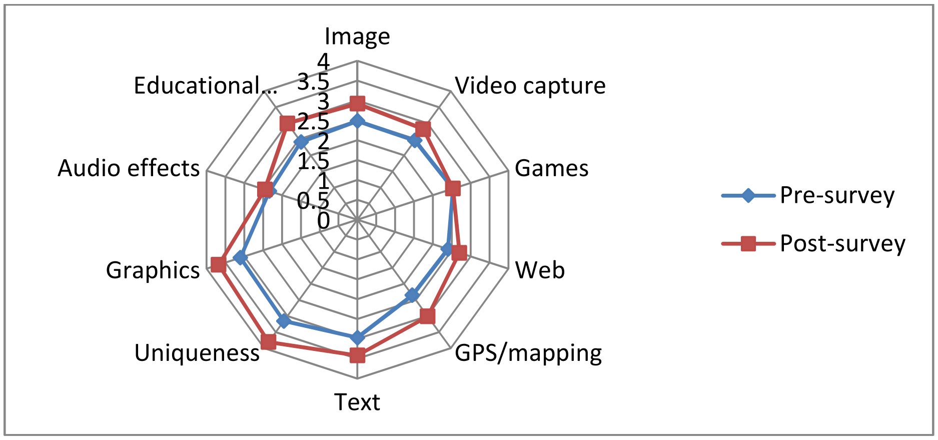

Figure 1(a). Self-reported knowledge gains with respect to the app elements (2015)

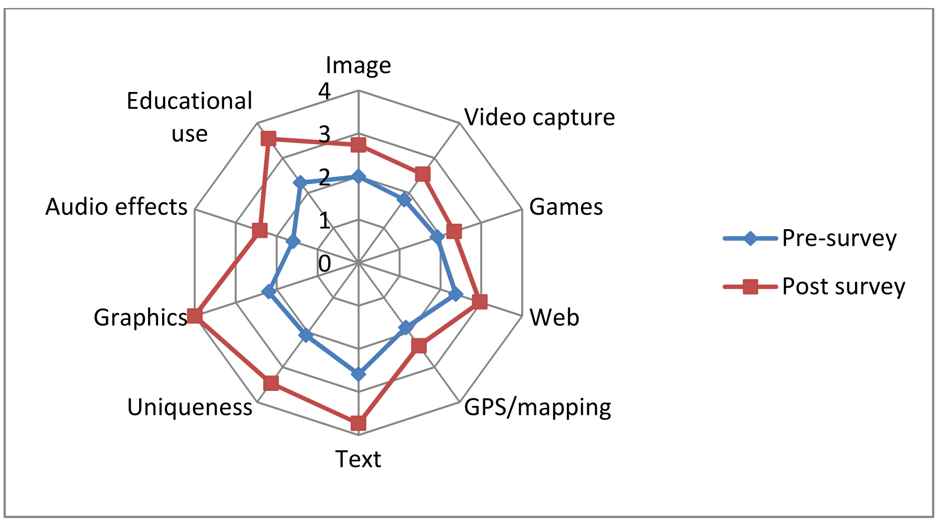

Figure 1(b). Self-reported knowledge gains with respect to the app elements (2016)

Table 1 indicates the results from the Wilcoxon Matched Pairs Test. We used Statistica for this analysis. The results indicate that the median difference between the self-reported knowledge gains at the beginning and the end of the course for the following app elements (e.g., text entry, graphic design, uniqueness and educational use) are statistically significant.

Table 1. Wilcoxon Matched Pairs Test, p <.0500

App Element	T	Z	p-value
Text entry	55.5	2.509	0.0121
Uniqueness	28.0	2.875	0.0040
Graphics	10.5	3.650	0.0003
Educational Use	36.0	2.374	0.0176

The students have also indicated that they know how to identify and define a problem when developing the app content. They have also reported that they know how to identify and define a solution when they encounter a technical problem when developing an app. The students indicated that they feel confident that they know how to create appealing graphics for their app. They also feel confident that they know how to make sure that their app addresses a real world problem. There is also a slight increase in their self-reported ability to work in collaboration with their teammates to solve a problem. The students are also able to envision their target audiences. They report that they know who the users of their app will be and they have taken steps to make their app user-friendly. Figure 2(a) and (b) show these results for the two years.

Discussion:

This course has benefitted from our observational and pedagogical studies with undergraduate students. Those experiences have improved the course we offer to high school students. This process also benefited from an industrial grant to increase their engineers' design productivity. We put those lessons to good use here to develop a 3-week intensive course. We will provide reference on those aspects in the final paper. It also should be noted that each semester that we have offered such a course, technology has gotten more and more sophisticated, with a rapidly changing software development environment, APIs, online references, licensing info, etc. It is truly impressive what these high school students have achieved in three weeks. They are assets to whichever university they chose. Though we have not tracked them officially, we believe that most of the first year's graduates have joined STEM programs. All our apps are free to download and are published at two Github repositories [MODS 2015, MODS 2016]. We have also initiated the development of a container app to help the visitor to download only those apps that match a certain theme or specific interest. This container app can help personalize a visit across several museums. Note that student apps are not updated to provide a standardized look and feel, but maintained in their original status, as submitted by the student teams. Thus there is no effort to 'take over', but only to disseminate student triumphs back to the community in their original form.

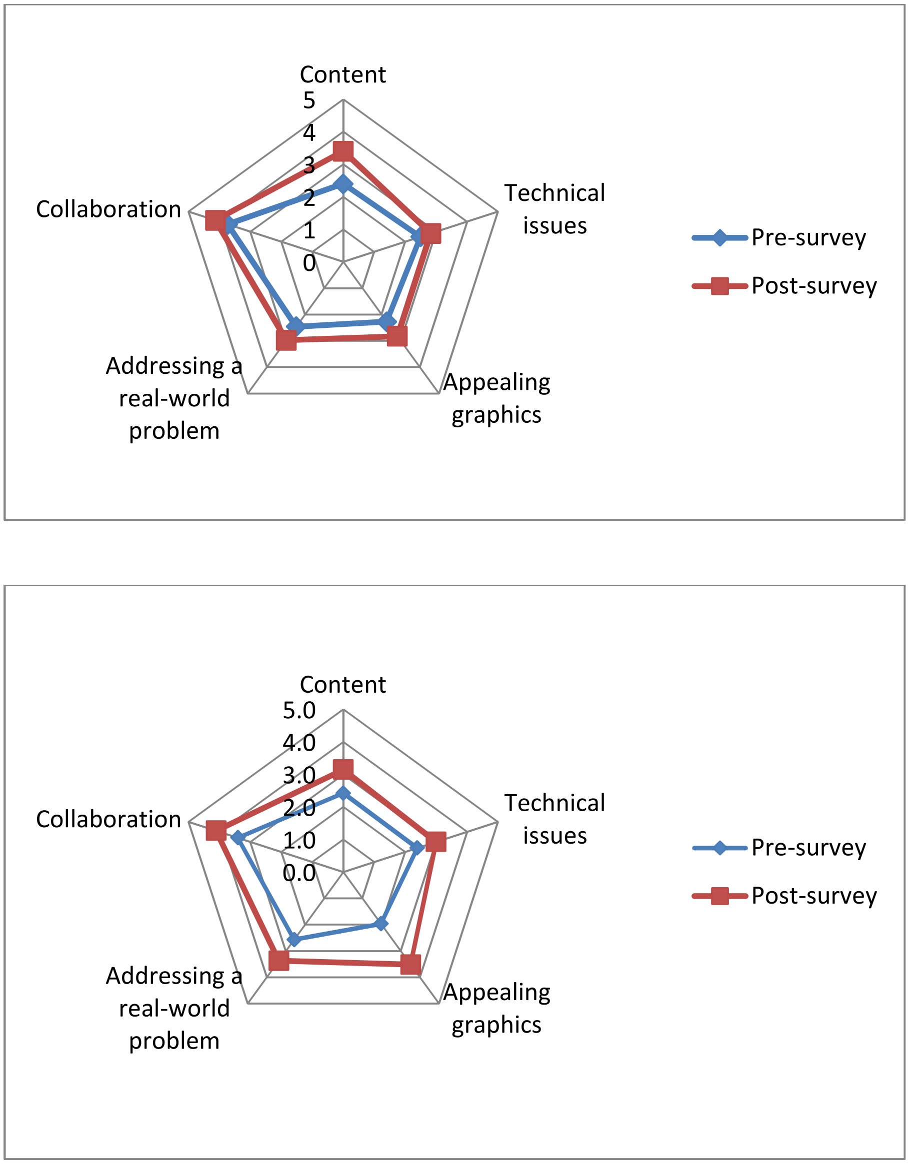

Figure 2 (a) and (b). Self-reported problem-solving skill gains in 2015, and 2016. The students are responding to questions starting with "I know how to develop content, solve technical issues, etc."

Benefits to Partnering Institutions: Our museum (MODS) has benefited from much better community relations, more visibility for the museum in the community, an amazing opportunity to interact with the local community, and outstanding student apps to add to the STEM center at the museum, thanks to funding from the United Way to realize this internship program. The museum also received recently another grant to build the container app mentioned above. Our university (FAU) also has seen the tide turn. Prior to the start of this program, our colleges' summer dual-enrollment program attracted only students from one nationally ranked high school. These students eventually went elsewhere for their college education. We probably were unable to compete on the prestige or scholarship front. However, with this integration of the informal and formal learning, parents and students know that local quality college education, that is also affordable, is a realistic option. We attracted one student from the first year, and expect to attract three from the second year group.

Longitudinal Study: In the second year, we decided to tease out the effect of the museum experience and separate it from the experience gained at the university. We collected pre and post surveys (hard copies) and entered them into Qualtrics. Results are yet to be analyzed. We will present the results at the conference.

Validation of survey results: We had a unique opportunity the first year of this program. Since we were transitioning out of the other program (see notes above) to this program, we ended up offering our summer course to two groups: One group (the 'museum' group) that had undergone the informal learning at the museum, and another (the 'non-museum') group that had not. Results showed that the non-museum group did not see the same level of improvement that the museum group had achieved. The differences were significant. Our longitudinal study will help us understand the additive and/or compounding effect the combination of informal and formal learning may have provided. This difference in self-perception was also echoed by the judges (most of the judges were the same for both the groups in 2015) in their comments after listening to student presentations.

Applicability to other students: For our APP-titude program, the eligibility criteria was set at slightly above 50% national percentile ranks for tests such as ACT and SAT. Though slightly above average by national standards, their achievement in our program, nonetheless, was outstanding by any comparable standard. Success here motivated us to initiate an outreach program to middle school students in a poor neighborhood. It is an after-school program to teach them computer science. Initial feedback from this group of underrepresented minority students has been positive. Another paper submitted to this conference documents that (Sifat et al., 2017).

Conclusions:

Our program has seamlessly combined informal and formal learning in an effort to motivate our diverse high school student community to attend engineering programs. Underrepresented minority students and girls were well represented in the student groups who underwent this program. Their comments, self-reports, and the sophistication of the apps developed attest to an increase in their interest in STEM and Engineering. In Year 3, we will migrate to a platform independent method for app development, so our apps can be launched on any smartphone (iPhone, android, or Microsoft). This is critical for keeping the museum visitors' experience satisfactory.

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