Reflections and Measures of STEM Teaching and Learning on K-12 Creative And Performing Arts Students

Abstract

Despite the fact that many students with interests in the creative and performing arts have the potential to be successful in science, technology, engineering and mathematics (STEM), they often rule out pursuing careers in STEM. We argue that one reason for this is the broader societal dichotomy between creative and technical fields: students often either like STEM courses *or* arts and humanities courses. The goal of our program is to capture students' perceived interests and support them in coming to see the relationship between the creative and performing arts and broader STEM concepts. This goal was accomplished through the design, development, and implementation of a variety of inquiry-based labs. These labs, which were developed primarily by undergraduate and graduate engineering students, focused on a diverse set of topics including image processing, robotics, bioinformatics, and audio processing. Project staff implemented these labs to students in an arts magnet school that is part of a large urban school district.

In this paper, we discuss preliminary results from the first two years of the project. In particular, we will focus on (a) a brief description of two labs (which are some of the labs available at http://dk12.ece.drexel.edu), (b) the effectiveness of the labs by assessing i) overall K-12 student attitude change in the program and ii) graduate and undergraduate experiences and development, and (c) lessons learned thus far in the project.

Rationale of STEM for Artistic Students

At an early age students are encouraged, both deliberately and inadvertently, to excel at their proficiencies and strengths, which can be equally mathematical, artistic, reasoning, designing, etc. The tendency to play to one's strengths at an early stage of a student's development can be ultimately self-fulfilling, leading students to avoid or underperform in subjects that lie outside of their proficiencies. A student who excels in the arts from an early age may believe they will never be good at math and science. This is particularly important for students who self-select into magnet schools that have particular identities that can further silo students into particular career paths. In this project, we seek to develop learning opportunities that can support students in connecting their interests with STEM concepts and correspondingly, increase and broaden the career opportunities for students of the creative and performing arts. Along these same lines, we feel it is important to note that students who choose intensive study in the creative and performing arts do often have the ability to succeed in mathematics and science and that by helping them see the connections between their interests and aptitude in STEM, we are broadening the pipeline for individuals pursuing degrees, and ultimately careers, in STEM.

This work builds on research in the learning sciences as well as existing work supporting the integration of STEM and a variety of student interests. Research based on the theory of Multiple Intelligences suggests that teaching of concepts and subjects can be more effective through the use of alternative methods and perspectives that appeal to a different set of skills than traditional pedagogy, but that may be better suited to a student's cognitive profile[1]. In this project, we developed and tested inquiry-based multimedia lab activities to appeal to several different intelligences. A variety of research programs have called for reform in the teaching of mathematics and science to bridge mathematical methods to interests [2, 3, 4, 5, 6, 7]. Rice University's INFINITY project [8, 9, 10] is a pioneering collaboration between schools and industry leaders to establish an engineering curriculum at the high school level that can motivate and attract students. Also previously, multimedia inquiry-labs have been developed [11, 12, 13, 14], but most have not been designed and administered by university students, and none have been quantitatively assessed for K-12 or university student attitude changes. We address these issues in this paper.

The Drexel K-12 Program at the Philadelphia Creative and Performing Arts High School

The aim of the DK-12 project is to teach K-12 students about the principles of STEM through current technology and inspire them to pursue STEM careers. The project plans to implement this through the use of highly interactive laboratories, designed for students in high school, whose designated major of study include those in the arts and humanities. Through the collaboration of Drexel Universities students and faculties, as well as the teaching faculties at the Creative Arts and Performing High School (CAPA), DK-12 implements laboratory exercises that teach the applications and principles of STEM knowledge and the intellect that goes into their use and development.

Goals of the project include:

1. Development of computer based laboratories that illustrate STEM principles that go hand and hand with creative expression and performing arts
2. Evaluate the effectiveness of these labs by seeing improvement in STEM based education within an arts magnet high school
3. Excite university students about teaching and open their perspectives on learning
4. Train teachers to implement STEM based content into the current high school curriculums

Our partner high school, CAPA, is a special admission magnet school, meaning that all students within the school district may apply for admission, but that admissions are highly selective based on the school's criteria. In the case of CAPA, in addition to demonstrating past academic achievement (a B average is required), students must apply and audition specifically for one of six fields or majors offered by the school: creative writing, dance, drama, instrumental music, vocal music, and visual arts. In addition to specialized instruction in these fields of creative and performing arts, the academic curriculum of CAPA is fully compliant with the requirements of the School District of Philadelphia and the State of Pennsylvania, following a standard progression in English, social science, mathematics, and physical science. CAPA attracts a socio-economically, racially, and ethnically diverse population from throughout Philadelphia and its suburbs. Over the past five years, the racial and ethnic composition of the school's student body has been approximately 44% Caucasian, 43% African American, 7% Latino, and 6% Asian. CAPA 9th and 10th grade students score higher than the national average at or above 90% in reading and language, but at 83% and 73% in math and science, respectively.

Goal 1: Lab Development

All labs were designed to be inquiry-based and capitalize on interactive technologies to support student learning as well as to keep them interested in the lab activities. The labs were developed primarily by undergraduate and graduate student research assistants along with input from Drexel University engineering and education faculty. The lab development process utilized a design-research perspective, where labs were developed by project staff, implemented with school students at CAPA, and revised and refined to improve the students' learning experiences to better achieve Goal 2 of the project. Two of the many labs developed are discussed below.

Labs developed by the Students

Steve Essinger developed a bioinformatics lab forensics investigation and took ownership of the ``Image Processing lab" previously designed by Adheer Chauhan[15]. The image processing lab was the main focus of his efforts so we focus on this lab for his reflections. The image processing lab developed for the program was intended to provide a connection between the artistic manipulation of digital images and the math, physics and computer science that enable software suites such as Photoshop or Apple Photo Booth that make image manipulation possible. All three algorithms taught to the class were selected to be simple enough to be carried out as handwritten exercises, yet powerful enough to show a substantial change in image content once the algorithm has been executed on the computer. Through the simple exercises the students were, perhaps unknowingly, being primed to look at mathematics and science in a pragmatic fashion that has direct impact on their daily schoolwork. Correspondingly, this lab has been specifically tailored to high school students with a chosen focus in the creative arts. In the following illustration the students take their picture in Apple's Photobooth, pretend that noise has corrupted it, and then attempt to clean it up with a mean/median filter.

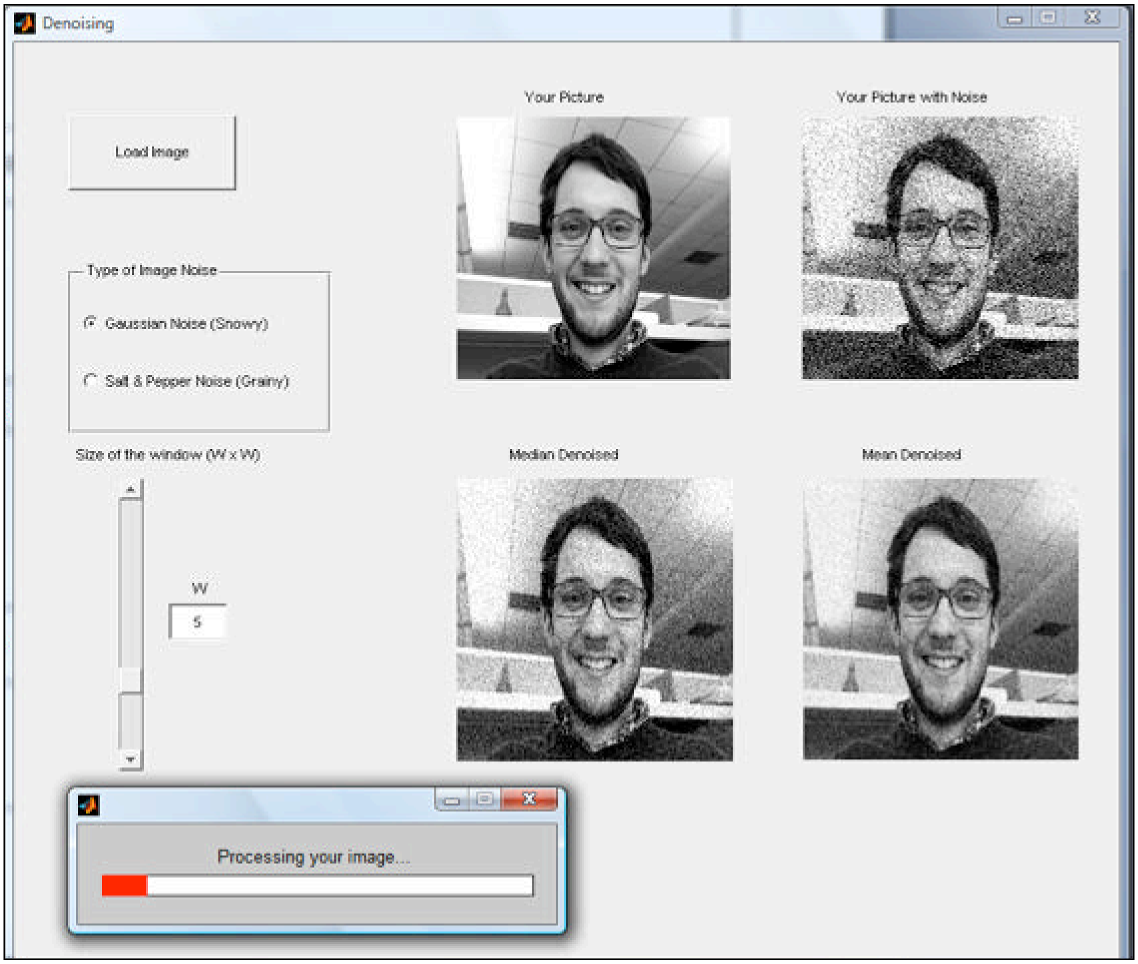


Fig 1: The Denoising activity of the Image Processing lab. See more of the lab on our website: http://dk12.ece.drexel.edu.

Ryan Coote developed a robotics lab to introduce the students to robotics, programming, measurement, and geometry concepts. Students completed several different activities that were related to calculating the distance they wanted the robot to travel by programming velocity and time, thus the students had to learn the relationship of distance, time, and velocity. The students programmed a time, t, in seconds, and a distance, d in centimeters, into the iRobot and compared how a cargo-load changes the expected distance traveled. The students were also given a challenge to have their robot navigate a maze as shown in Figure 2. They were awarded extra points if they used geometry concepts such as sine, cosine and tangents to estimate the angle-turns of the maze. It was a highly intricate and dynamic laboratory. The lab also demonstrated measurement error via requiring the students to conduct multiple trials so that they could compare theoretical and predicted calculations with what they actually measure in real life. By calculating a theoretical distance and then comparing it with the distance that they measure they either get the exact distance they wanted, a distance that is shorter or a distance that is longer in comparison. The lab also introduced the concept of drag by using weights on the iRobot. Students were able to see how it travels when weight is added to it, whether the distance is shorter or longer from previous test. Figure 3 shows the students in action working on the lab.

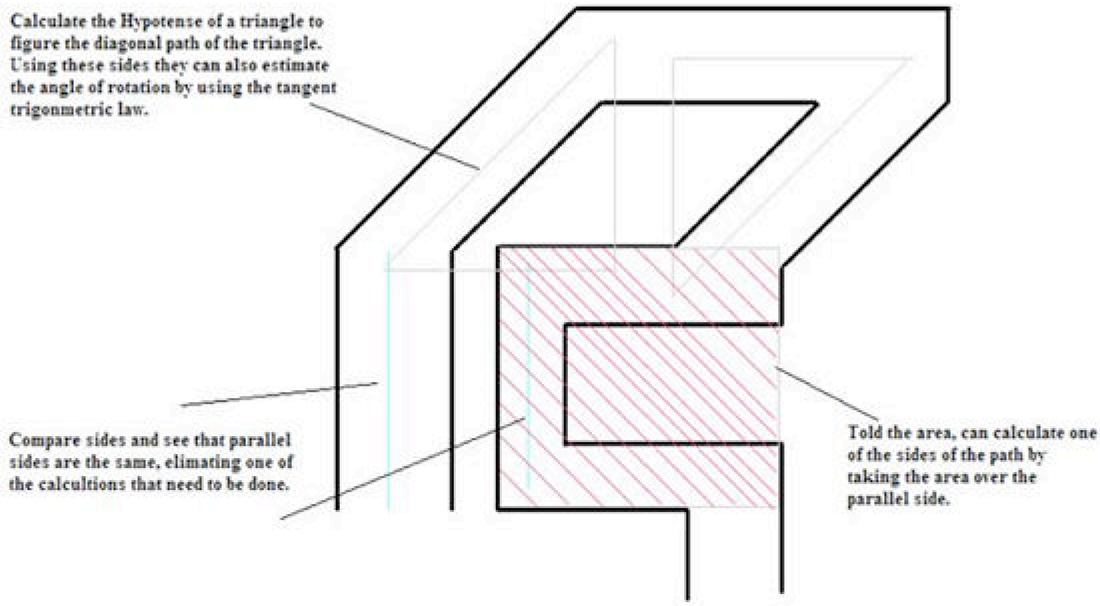


Fig 2: Schematic of the maze activity of the iRobot lab.

Through the Drexel Research Experience for Teachers (RET) program, Pete Konstantopoulos participated in each lab discussion and offered suggested improvements based on his particular classroom structure. His primary focus was on helping the graduate and undergraduate students develop the lessons and labs they would eventually use in his classroom during the school year. In addition to consulting on lesson development he also spent some time learning how to use Matlab; specifically the bioinformatics toolbox and he was particularly involved with improving the image processing and robotic labs.

Staff Reflections on Implementations of the Labs

The university students found that the implementation of the labs was a balancing act between keeping students attention and engagement and making sure the lab concepts were learned. They found that using several styles: lecture, class discussion, activity sheets, and working in a group on a computer was enough diversity to keep most students engaged. For the iRobot lab, mostly a hands-on approach was used, but some students were given the option of taking different roles: a) programming, b) measuring, and c) calculating the measurements and geometry on paper. The students were asked to write their reflections on the outcomes and challenges when implementing the labs, and we show the unedited writings in the following paragraphs. From these excerpts, we see that both styles were able to capture students' attentions.

Graduate Student, Steve:
"In order to capture the students' interest with the lab we had ensure that we were not lecturing them for extended periods of time or burying them in detailed signal processing concepts. To keep the students engaged we chose to incorporate several teaching methods that we felt would appeal to the majority of students while also enabling us to communicate our material in a clear manner. Each activity began with a brief lecture to introduce the concept, math, physics and motivation behind the topic. The topics focused on image processing algorithms that make use of

simple statistics such as mean and median. We also incorporated a section on the Gaussian distribution and the concept of noise.

The lecture evolved into class discussion allowing students to probe the topic further and answer each other's question where applicable. At the 10-minute mark we would wrap up the discussion and pass out activity sheets for the students to complete. These sheets had a matrix of pixel intensity values representing a segment of a digital image. The students would work individually to implement the algorithm discussed prior for about five minutes. Once the students had completed the exercise and we cleared up any unanswered questions the students moved into small groups each consisting of 2-3 members.

At this point the students have learned the basic concepts involved in digital image manipulation and have labored over a mock image implementing the math algorithm previously learned. To illustrate the significance of their time spent on the worksheet we provided each group with a laptop computer with a custom Matlab GUI we developed implementing the exact algorithm the students have just worked with. To grab the students' attention we had them take a snapshot of themselves using the webcam on the laptop. This image was then imported into the GUI so that the students could carry out the algorithm. Not only were we interested in showing the students the artistic power of the simple math algorithm on their own image, but also gain an appreciation for the computational power of a computer.

The students continued to work in groups experimenting with the algorithm for about ten minutes. For the last five minutes we passed out a note card to each student asking him or her a question pertaining to the material we have just covered. This provided us with real-time feedback on the knowledge they have just acquired and their command of the material. This concluded one activity for the lab and we repeated this process for the remaining two activities.

Fig. 3: Geometry students working diligently on the iRobot lab. Here they are investigating the impact of a cargo-load on the expected distance traveled. They conducted several trials to learn about measurement error and significant digits.

Undergraduate Student, Ryan:

"The content was designed around the intent of having students using the iRobot and getting on the floor to measure its distance of travel. Keeping this mind an activity was needed where the distance travelled by the robot was important and the approach to programming the distance could not just be done by simply plugging it in. The idea of a stop zone was applied, where the robot would start at a point and would have to travel a certain distance to get into the zone. The way the distance was programmed into the iRobot was through its speed and time commands, a combination of how long it would travel for a certain speed would make the robot travel at a distance.

To implement this lab two days of class time were required and students needed to be in groups of 5 or 6 depending on the size of the class, this allowed us to divide the iRobots and computers among the groups, and have the students share the data with each other in their respective groups. On the first day the Stop zone challenge was the first activity where the group would try a speed and time to get the robot into the zone; based on what speed and time they used they would calculate the distance that was supposed to travelled from using this speed and time then the students would measure the distance the robot actually travelled. Here is where the comparison between predicted calculations and real world results would take place; students would probably see a difference in values that could be based on factors such as slight swerving that was done on part of the robot, measurement error done on part of the group, or the robotic motors overcompensating for the path of travel. Once the first stop zone challenge is done students can then grab something with significant weight, we used bricks during our sessions, and then use the same speed and time to try and once again get the robot into the stop zone with this added weight. Based on the weight that was added a difference in distance may or may not occur, regardless the students are asked about they think may have caused a difference in the distance measured in between adding weight. These inquires are tested by adding more significant weight to the robot and comparing the distance in between trials of added weight testing the difference in the measured distances. On the second day students get a chance to program the robot to help it navigate through a maze. The premise for maze navigation is simple have it start at one position of the maze and have it finish at the end of it, students are expected to measure sides of the maze to help program the robot to navigate through the maze and to estimate the angles at which the robot has to turn. Considering the amount of time that the students have to complete the maze it is suggested that they get it done in as little trials as possible by using geometry relationships. "

Fig. 4: Ryan Coote, undergraduate student in electrical engineering at Drexel University and the mastermind *designer of the robotics lab*, gets ready to hand out the measuring tape to the second period class. Ryan's lab is the most hands-on lab of the project so far. It has students measure distances, Figure out the distance-time-velocity relationship in order to program the robot, and actually change parameters in and compile code to use the robot. Despite all these aspects of the lab, students quickly got a hang of it, and what Ryan thought would be the most challenging task – navigating the maze -- ended up engaging students the most, and therefore they were up-to-the challenge and (measured all the distances, calculated the angles), completing the maze challenge in 20 minutes!

The K-12 teacher found that students' interests were peaked even if there was too much material being covered or if it was academically advanced. He also notes that the labs left the students curious and wanting to know more about the scientific underpinnings of the lab. This is exciting because perhaps we can issue "Further reading" and encourage students to find out more independently after we have been in the classroom.

K-12 Teacher, Pete:
"When it comes time for the university students to perform the lab in the classroom, they are routinely surprised with how quickly the 50 minutes can go by. With the Robotics Labs, we developed a very ambitious series of tasks for the students to complete, and many students were not able to complete the lab. This lab was academically challenging to the students. The students were engaged in covering units to fit into the program, and measure distances and degrees of angles to complete the maze, they also understood how this lab related to the work we do in the class.

The students also enjoyed the image-processing lab. Many of the students are visual artists and use Photoshop in their graphics design class. It's an easy connection between their *arts area and the STEM field. Since averages are a topic that is covered in our math curriculum, the students had a lot of success. The students found the lab challenging, but also easily understandable. As always, the students did get a little distracted with the Photobooth application on the iMac. An easy way to deal with this, and something we did, is to expect the students to play around with it. Let them play for a few minutes and then redirect them to the activity they need to accomplish. All the activities had clear instructions and the students were able to follow along without issues.*

Aside from the time constraints, there is a delicate balancing act that happens when you are teaching a class or creating a lab. How do you properly break down the material you want the kids to learn so that it is understandable, and yet, challenging at the same time? During the forensic science lab, many students felt that they just plugged information into a computer program, and the computer told them the answer. Many students wished they had a greater exposure to the science behind the activity.

The level of engagement for the students was always high. Even when the students didn't understand how this fit into the curriculum the labs were interesting to the students. During the labs that the students felt didn't engage them, two or three students would get off task in each class, but most were still interested in the concepts behind the lab, probably due to the fact that most students are also taking Biology, and many of the topics in these labs overlap. "

Goal 2: Effectiveness of Implementations

I) Overall Attitude Changes of the K-12 Students

We discuss two preliminary analyses of the effects of our implementations on the CAPA students. First, we reviewed responses to pre-and post-surveys and coded the responses to four open-ended survey questions dealing with the connections between the creative and performing arts and STEM. Second, we report in analysis of quantitative survey data regarding interest in STEM. Data for this section comes from pre-surveys participants completed at the beginning of the 2008-2009 academic year and post-surveys from the end of the academic year that were completed as part of the project evaluation process.

Connections between Creative and Performing Arts and STEM

In this section, we focus students' responses to four open-ended questions from the pre-and post-surveys:

- Do you think it is important to understand the scientific ideas behind common everyday activities such as cell phones, iPods, digital video, etc. (even if you don't currently understand them completely)? Why?
- In what ways do you think mathematics and science and the creative and performing arts are related?

Responses were coded using the following coding scheme:

- No response
- Canonical Response, unrelated to project activities and unspecific (for example, *"Math and Science are all around us"* or "*Mathematics is the language of science*" or "*Anatomy and dance are related*" or "*It will help us fix stuff."*)
- Specific connection between STEM and the arts

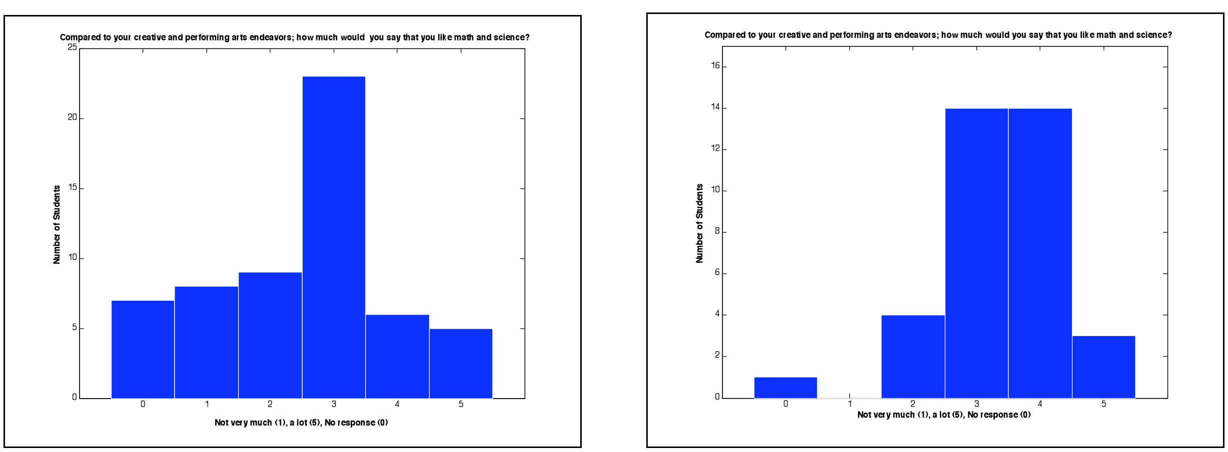
The following data summarizes the survey results from the two items (72 students completed the pre- and post surveys):

Survey	**No Response**	**Canonical Response**	**Specific Connection**
Pre	62	82	0
Post	39	78	27

From the data above, we see that a significant portion of the students posted no response to the item and those that did respond included a canonical response without any specific connection between the STEM and the arts. In contrast, on the post-survey, we see a portion of the responses (19%) contained a specific connection between STEM and the arts. While not all of the connections were explicitly related to project activities, it does indicate a particularly direct result of the project activities.

Students Interest in STEM

Other survey items asked students to rate their perception in a number of STEM and project related areas, including their interest in STEM. While there was weak, but statistically non-significant differences between the pre-and post- surveys for most of the items, one item does shed light on students evolving interest in STEM ideas. The item asked students to respond to the question "Compared to your creative and performing arts endeavors, how much would you say that you like math and science?" on a Likert scale from 1 (not very much) to 5 (very much). The graphs below display the results from the pre- and post-surveys for this item.



(a) (b)

Figure 5: Students' responses to the pre-survey (a) and post-survey (b) assessment question: "Compared to your creative and performing arts endeavors, how much would you say that you like math and science?".

Results from this item show on the image processing pre-survey, students have a low-to-marginal interest in STEM. The trend for the image processing post-survey shows a shift towards a marginal-to-high interest in STEM once they have learned how STEM applies to image processing.

II) Assessment of University Student Learning

One of the tacit goals of this project was to support graduate students learning through active engagement in both the development of labs to expose school students to STEM concepts and engagement with school students in the context of their developed labs. Because of the small number of university students participating in this project, we use qualitative research methods to document their learning. In particular, we conducted interviews with two university students, one graduate student and one undergraduate. The interview questions focused on the students' experiences with the labs, their goals for the implementations, and further reflection on their work in the project. The interviewer took field notes during the interviews and the interviews were audio recorded.

In order to analyze the interviews and to begin to be able to characterize university student activity and learning within the project, we conducted analysis at two levels: global and constant comparative. For the global analysis, we reviewed the entire interviews chronologically and annotated the field notes generated during the interviews with a first round of hypotheses regarding patterns in university student beliefs, activity, and project engagement. This phase of analysis serves to help the team get a sense of the data and will allow for the identification of segments of theoretical importance. Then we used an adaptation of the constant comparative method described by Glaser & Strauss[16] and refined by Cobb and Whitenack[17], to test and refine the initial hypotheses. This process involves reviewing the previously generated "local" conjectures against the entire data corpus and, for each conjecture, assessing its fit with the remainder of the students' contributions to the interviews. Ultimately, the result of this analysis is a number of claims about student activity, engagement and learning "that span the data set but yet remain empirically grounded in the details of specific episodes"[18].

Theme #1: Connecting Students and STEM: **Everyone can do math**

While this project was initially predicated on the goal of helping school students connecting both their interests and popular culture with STEM, understanding and supporting this connection did not come easily to the university students. University students' initial perceptions about making this connection was heavily based on the content or the technology – it was a common belief that school students would see the connections by "playing with the technology" or by "getting a glimpse at the theory behind technology such as iPods (for those with music interest) or digital images (for those with visual arts interests)." After three semesters of activity within the project, we begin to see a shift from the technology being the source of connections to the role of the university students in supporting that connection.

RC: *"I really want to make sure that they don't see the subject matter as being so esoteric. Math is a practical application that I think everyone can learn and that was one of the things that was kind of cool about actually doing this lab. They already know the basics of this stuff … and we give them an opportunity to use it. … That was kind of like one of the coolest aspects of the lab, the fact that it was like an actual application and – to them – something that they could see the use of. And it was my job to help them make the connection, to help them … see what's going on behind the curtains and begin to understand why the things they use work the way they do. But again, it all starts with the stuff they know."*

SE: *"[My goal is to] massage and force the connection. … My intent was that they see that there was this math, filling in these boxes, and thinking "I kinda get that conceptually … and its kind of straightforward" and then the next step is to use the Matlab GUIs to experiment. My job is to help them see that with the Matlab GUI, they're using the same exact algorithms just discussed. So the progression, from simple, straightforward handwritten exercises to the algorithms that are being done by the software is designed to help them gain a much better appreciation of the mathematics and what it is actually able to help them do in practice."*

Theme #2: The importance of the project as part of the students' development: **Developing agency over the lab and the material.**

RC's initial thoughts about the lab was that he was supposed to have the students "Get down and dirty measuring and using the iRobot … because that was what Dr. R. told me to do." After multiple iterations, there was a shift towards more specific instructional goals. Initially, RC's goals were in the ream of programming:

"I really wanted them to get the idea of how programming works. Object oriented programming is very instructional. Its very syntax based. And it only really works by telling the robot exactly what to do: first do this, then do that, then do that… Its nothing too complicated."

In contrast to this initial input-output perspective, RC's ultimate goals for the labs emerged later in the conversation:

"Initially, I felt that the big thing they were getting from my lab was that "if I put this into the robot, then this should come out." But eventually, I saw that there was more to it than that. I began to hope that they would kind of see when everything's said and done, it was that this factor … it was thinking what could happen with this factor vs that factor … or what would happen with this factor could happen and how about this final factor … what could have happened so … that my final result might be what I expected. And if its not, what factors could have [trails off]."

In these excerpts, we see RC moving from goal that focus on low cognitive-demand tasks focusing on observing and recording outputs for a given input to a perspective that focuses on understanding the situation and engaging in legitimate problem solving. We see higher cognitive demand tasks such as predicting outputs, comparing different conditions, and inverse processes (inferring inputs based on a given output). While RC has yet to revise his lab design to include these features to reflect these higher-order goals, his utterances above, particularly in contrast to his initial goals, provide evidence of shifts in his underlying instructional goals for the lab.

I used to think I knew enough content to teach. As a result of their project activities, university students have begun to recognize and respect the depth and breadth of knowledge needed to teach STEM concepts effectively, even at the high school level:

RC: "I'll be honest with you, I would love to teach but, now I'm a little concerned. From working on this project, I've seen how important this stuff [cutting-edge STEM] is to teaching. The scariest thing is that if I went in to the field of education I would not be able to help my *students at an appropriate mental level. There are so many connections that I want them to see … like with every class I take, when I look back, I see connections that I think kids could make. That's one of the reasons I want to go to graduate school – to learn the detailed science that I want to teach some day."*

In this excerpt, RC connects teaching "to the appropriate mental level" with his own graduate studies. By "the appropriate mental level," RC is referring to helping students make connections, problem solve, and apply what they've learned and that he believes he needs deeper content knowledge in order to construct such learning environments.

There's more to preparation than knowing the content. While SE's affable personality allowed him to be quite good in front of a high school class from his first project experience, he realized that there was more to teaching than knowing the materials:

"There's more to preparation than knowing the content. The big thing I learned was the importance of preparation. When I first started teaching the labs, I kinda went and winged it. I knew what I needed, and I had worked on the lab … all the material was there (or so I had thought).

But as time went on, I realized that it was very important, especially when teaching STEM is to have a method. A methodology there and build upon it. Start very basic and then gradually add another layer. Until you get to the big picture and then highlight how all those different layers work together."

In this excerpt, we see SE focusing on developing a teaching philosophy that is consistent with research in the Learning Sciences that focuses moving students from acting on physical objects towards various levels of abstraction and generalization[19, 20, 21]. Moreover, SE developed this instructional strategy not from a textbook, but in a way that had personal and professional significance.

Reflections About `Lessons Learned' and Improvements for the Future

In this section, we see the staff reflections about the lessons learned. In the image processing lab, the major problem was the typical teaching problem of how to convey all the material in a concise and effective fashion while trying to maintain most of the class's attention. Some students were able to take the concepts one step further - when given an activity where they had to add colors to get other colors, one student said "Well, I know to take out Blue from the RGB (Red/Green/Blue color model) in order to get yellow". This shows the student extended the concept and thought of RGB as a ***subtractive*** color model in addition to ***additive***. The iRobot lab was logistically complicated since many parts were needed: iRobots, rulers, wooden boards to construct the mazes, duct tape, laptops, Bluetooth dongles, etc. There was also the problem that iRobots are well-known to "drift" resulting in unpredictability. The student was able to take this "fault" and teach students about **error**. Also, it was assumed that the students would find the maze project to be the most difficult and tedious, but surprisingly, the opposite was the case – the students took it as a challenge and one group even improvised and started negating their directions and taking complementary angles in order to reverse the trajectory through the maze. Such an action shows digestion of the material.

The major concerns from the teacher are that the labs were developed from multimedia concepts and then retroactively fit into the curriculum. The original thought was that particular labs should consist of individual modules that are based on one concept each. Then, these modules can be pulled apart and interspersed throughout the year. But the graduate students always thought of the labs as a whole and never curriculum-concept based. This demonstrates that university students should be pushed to make labs curriculum-based rather than focusing on "concepts" they think are relevant.

SE: "*Our hope and intent was to excite the students about the practical application of STEM to their chosen area of specialty, the creative arts. The surveys and note card questions administered to the students provided us feedback on their level of comprehension, but it is difficult to assess their enthusiasm for the subject. To assist us in our evaluation we video recorded sections of the lab so that we could later reflect on the participatory enthusiasm shown by the students. Our intent was to have every student actively participating in the lab activities. The video shows that many of the students were active with the lab and generally there were two to three students that dominated the discussions. We are also interested in knowing the long term impression this suite of labs have impacted the students and are currently seeking methods for long term evaluation.*

Another goal of this lab development was to expose me to a novel teaching experience through which I could further mature as a potential educator. My first draft of the image processing lab included a nine page packet of material for the students to read and follow along with in the lecture. This approach overwhelmed the students because the content was too dense for them to read, comprehend and apply in a thirty minute session. Generally, the students would become discouraged with the labs and choose to play on the laptops rather than participate. I realized that to communicate with the students I needed to actively instruct using demonstrations on the computer and blackboard. This approach was much more successful and reflects the current draft of the lab. The next step is to create an interactive PowerPoint presentation to show the students rather than tell them about the lecture content."

RC: *"Students participated in the lab so long as everything was connected properly and all of the equipment worked, there was great help and support from the teacher who worked with us and students were very well behaved. Students were able to calculate measure and compare the predicted distance they thought the robot would travel versus the actual distance that it did travel. Most of the groups of students were able to measure the robot travelling with one load and multiple loads allowing students to compare the rate of travel that the robot was doing. In one particular period students would use textbooks and bricks to see if that significantly weighed the robot down, the distance it travelled was compared to earlier tests to see exactly how much that mystery load weighed, whether it was close to one brick or two etc. During the second day of the lab only a few groups were able to do the maze runs with their robot, and numerous groups missed out on trying the challenge themselves due to time constraints, as a substitute a triangular path was made out of tape that the students would have to make their robot navigate, however this task did not carry the same amount of interest that the maze did. In most cases however the Bluetooth connection between the robot and the computer had to be constantly reconnected, this was one problem that was overseen in the planned implementation and had to* *constantly be fixed when the groups could not move their robot. Time was another constraint that was not planned for, students did not collect enough data to plot numerous trials with different loads causing them not to calculate a regression equation we were hoping that they would be able to find for their robot. The student participation and interest in the lab was very encouraging, once students received some data of the robot travel as well as calculated the predicted distance from the speed and time that they inserted, discussions would take place among students in their groups or even with their instructors and Drexel participants about the data they received. How it travelled farther or shorter than expected based on what load was used, was always factors that they were taking into consideration when asked to answer the notecard questions. During the maze runs student was enthusiastic and persistent; students in their groups would always continually run the maze constantly until they reached the end, one group even decided to run the maze backwards when they completed the initial for the first time.*

When asked about the notecard questions there was mix set of responses where it felt like some students responded to the question for the sake of making a response and where some students gave an pernicious view about the trials they conducted for the load test. A few students would ask the affiliated instructors or the participating Drexel faculty about what exactly happened for a few trials, in other cases there would be group talk about what they measured and why it happened. Conclusively students were able to give some coherent thought about what they saw, measured and compared, while a few concepts were missed a general idea about factors affecting was expressed in a majority of the notecard responses collected."

Pete*: "To ensure that all labs are as successful as the robotics and image-processing lab, the development of the lab should fall from picking out a topic from the curriculum. When I came to the program, several labs were already in development. To incorporate them into the curriculum involved some reverse engineering on our part.*

Many of the labs worked out rather well. When the students were engaged in the material, and a lot was accomplished. There were a few times the student's seamed confused and unsure what to do, and that's when the students stopped engaging in the material. Being clear about what the students need to accomplish is a goal all labs should meet. As stated, making sure the topics covered in the curriculum are covered in the lab will greatly help with the engagement and the success of the labs in the class."

Overall, the students realized that they needed to implement different teaching styles to get concepts across to students. The teacher notes that each lab should spell out the specific goals to be accomplished in a particular lab, so that the students are goal-motivated. Also, technological labs require much equipment, especially robotics, and this leaves a lot of room for parts and programs to break or be non-functional. So, we advise caution when implementing such complex-component labs.

Goal 3: The Students Reflections About Their Perception of Teaching and Learning

Overall, the students learned the value of instruction, and the difficulty of connecting theory to the real world. Of course, students only went into the classroom a total of 2-days for each of their labs, with a total of 4 weeks for the whole year. The university students felt like it were too little time, and their teaching style and lab development could have matured. Of course, this is due to their limited time schedules and resources of the project.

SE: "*I have a much greater appreciation now for teaching which includes content development, preparation and instruction. My approach strives to push the students to make connections between theory and application. Even if the connection is not readily apparent I try to keep the students actively involved so that they are primed to see the connection when it is unveiled during the lab. I have found that this approach is more effective than merely telling them the connection and moving on. I intend to continue this approach as we move to develop other future labs for the program.*"

RC: *"I enjoyed the short time that I had doing this lab with the students and I wish instead it were an ongoing project versus a two day experience. This has taught me that there is little to not enough time to make sure that students are learning what they need to, and in most cases it feels that they cannot apply concepts formulas and equations to a situational setting causing it to be perceived as book knowledge. The project makes me want to teach in a way but in an environment where one could coach on how to think and react versus just solving a problem or know a fact. Learning should be an applied process as much as it is one where you intake concepts and it is important that learning is applied in some way due to the thinking that comes as a result of conducting an activity that is not trivial."*

Overall, the university students participating in the program gained valuable teaching experience, and it had a positive impact on them. They realized the intricacies of teaching, and they became acquainted with their learning style and how it differs from others. Each student enjoyed working on applied problems that would help K-12 students connect abstract concepts to the real world.

Conclusions

Above, we have described our results for the first three goals of the project. In summary:

- We have used a design research perspective to create, test, and refine a set of inquiry-based, interactive labs that are freely available to teachers. All labs and lab manuals are available at http://dk12.ece.drexel.edu.
- Throughout one year of implementation at the Philadelphia High School for the Creative and Performing Arts, we see marked increase in students' awareness of particular connections between STEM ideas and the creative and performing arts. In addition, we see a change in students' interest in STEM concepts after participation in project activities.
- Developing and implementing the labs with school students is a potential site for university undergraduate and graduate student learning. In particular, we observed increases in university students' beliefs about equity in STEM instruction. Furthermore, individual university students showed increases in their agency over the lab and the material and personally experienced the content and pedagogical knowledge needed to teach STEM effectively.

These results indicate that we are well on our way to meeting goals 1-3 of the project, though additional data and more rigorous analysis is needed.

In conclusion, through the Drexel-CAPA program, we have found that not only the K-12 students attitudes changed towards STEM, but also the university student's attitudes towards teaching and learning changed. The teacher was invaluable with giving feedback of how to take these labs into the classroom. The university engineering students became more proficient at communicating to a wider audience leading to several different realizations: 1) the students not only had to know the material well, but they had to develop a methodology to teach it, and 2) realize that the teaching methodology must reach several learning styles. Finally, the university students were more appreciative of good teaching and the effort this takes, and the K-12 teacher was able to assist them in their teaching process.

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