

Mechatronics Mania at the Inaugural USA Science and Engineering Festival

NICOLE ABAID, CARLO YUVIENCO, VIKRAM KAPILA, and MAGUED ISKANDER

As the need for science, technology, engineering, and mathematics (STEM) professionals grows in the United States, the interest of students in STEM disciplines continues to decline [1]–[3]. To foster excitement for STEM subjects among K–12 students, outreach and informal education programs often aim to infuse STEM fields with the energy typically reserved for activities such as sports competitions [4].

The month-long inaugural USA Science and Engineering Festival in the fall of 2010 was sponsored and supported by over 500 leading science and engineering organizations [5]. The finale of the festival was a large expo, held in and around the National Mall in Washington, D.C., on October 23–24, 2010. The expo, which consisted of over 1,500 booths, was visited by over half a million people in two days. The goal of the Festival, to “reinvigorate the interest of our nation’s youth in... STEM by producing and presenting the most compelling, exciting, educational, and entertaining science gatherings in the United States [5],” was taken up especially at the expo, with booths housing a wide variety of interactive exhibits. For example, visitors were encouraged to walk on water (and corn starch), look at solar plumes through a telescope, and spread virtual viruses by means of tagged wristbands.

The potential of robotics and mechatronics to inspire students to pursue STEM fields has been investigated in numerous formal [6]–[11] and informal [12]–[15] learning environments, which have been shown to increase student performance on standardized tests [16] and has been lauded by President Obama [17]. To capitalize on this potential, a National Science Foundation (NSF)-supported GK–12 Fellows project at the Polytechnic Institute of New York University (NYU-Poly) titled “Applying Mechatronics to Promote Science (AMPS)” has strived to enhance STEM learning in central Brooklyn schools with an infusion of mechatronics and robotics [18]. Since its creation in 1999, the GK–12 Fellows program has funded almost 300 projects nationwide [19]. The GK–12 Fellows projects aim to enhance K–12 students’ learning by pairing school teachers with STEM graduate fellows to create and teach exciting STEM lessons. AMPS Fellows, who perform cutting-edge

graduate research in marine systems, collective behavior, robotics, smart materials, image processing, biosensors, protein engineering, biomolecular diagnostics, and directed drug delivery, are paired with elementary, middle, and high school teachers from central Brooklyn public schools. These instructors work together to enhance STEM learning by incorporating mechatronics-based activities and demonstrations in the classroom STEM lessons [7], [11], [20].

In spring 2010, the AMPS project was invited to participate in informal science education at the USA Science and Engineering Festival Expo, as one of 15 programs selected to represent the NSF. The AMPS exhibit, called “Mechatronics Mania,” housed various interactive mechatronics projects, including a mechanical advantage apparatus, a bioinspired robotic fish, a LEGO image scanner, an audio-enabled hexapod robot, and several iPhone-controlled devices. The projects for the exhibit were designed and operated by the fellows, teachers, and faculty, who interacted with thousands of visitors over the two days of the Expo.

In this article, we describe the formulation and components of the projects presented at the Mechatronics Mania exhibit. In addition, we report on the reflections of fellows and teachers about their experiences at the Expo. Finally, we assess visitor experiences through responses to a survey designed to elicit demographic information, interest in STEM, and mechatronics knowledge gained from interactions at the exhibit.

MECHATRONICS MANIA

Upon selection to the USA Science and Engineering Expo, the AMPS project hosted an internal competition among its fellows and teachers to develop adaptations of engaging STEM classroom demonstrations for the setting of informal learning. Fellows in the AMPS project usually spend their summer months in partnership with teachers developing classroom-relevant STEM lessons, which are designed for one or two 45-min class sessions. The fellows and teachers were now challenged to convert these lessons to suit the informal and brief setting of the expo.

In the several months leading up to the expo, three trial auditions were conducted during which fellows presented their concepts, demonstrations, and final prototypes to a panel consisting of the AMPS project faculty investigators and fellows’ research mentors. The fellows either

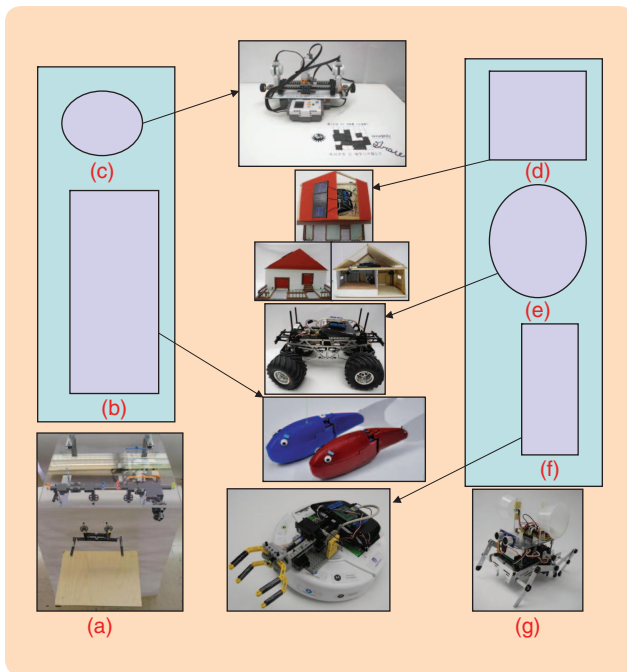


FIGURE 1 Schematic of Mechatronics Mania exhibit floor plan, with projects pictured in insets. Projects pictured are (a) the mechanical advantage apparatus, (b) bioinspired robotic fish, (c) LEGO image scanner, (d) iPhone-controlled house, (e) iPhone-controlled truck, (f) iPhone-controlled Create robot, and (g) audio-enabled hexapod robot.



FIGURE 2 AMPS Fellow Jennifer Haghpanah discusses the mechanical advantage offered by pulleys to lift a load with a young visitor. (Photo courtesy of David Lopez, undergraduate research assistant, NYU-Poly.)

received constructive feedback for further enhancements or were excluded from further participation in the competition. In addition, all fellows were filmed to improve their presentation and delivery, which is a core goal of the GK-12 Fellows program. This activity provided additional training and practice for the fellows prior to engaging an audience of thousands of young learners.

From the 12 fellows, seven demonstrations were selected for presentation at the Mechatronics Mania exhibit. The seven selected activities translated the formal STEM activities of fellows and teachers into an informal setting to engage free-choice learners of all ages through brief demonstrations and interactions. A schematic of the activities presented in the Mechatronics Mania exhibit is given in Figure 1. These activities included the mechanical advantage apparatus; a bioinspired robotic fish; a LEGO image scanner; an iPhone-controlled house, truck, and Create robot; and an audio-enabled hexapod robot.

The mechanical advantage demonstration, seen in Figure 2, featured a pulley system operated by two LEGO NXT bricks. One brick acts as a remote control with a dial to enter motor speed and two buttons to actuate the motors. The pulley system allows for lifting a load in the absence and presence of two moving pulleys. In the absence of pulleys, the user observes that the motors can lift only about 100 g. However, after introducing the pulleys, the user can actuate the motors to lift much heavier weights.

Bioinspired robotic fish are constructed from custom plastic body shells and electromechanical components. The fin portions of the fish are actuated by an internal servomotor, enabling underwater locomotion. In addition, the fins of the robots are interchangeable and are offered in various forms, mimicking different species of fish such as shark, jack, and guppy. Participants were further able to control the frequency, amplitude, and offset at which the servomotors are actuated. Through this demonstration, users were able to explore the role of fin geometry in swimming after testing their modified fish in a colorful pool of water.

The LEGO image scanner demonstrates the basic principles behind scanner technology. The key component is a LEGO light sensor, which consists of an emitter-detector pair capable of detecting the light reflected off of a surface. Users were given the opportunity to compose their own images to be scanned using a grid-like template. The template is situated underneath the light sensor, mounted on a two-dimensional traverse stage, which is constructed from LEGO components. The data are relayed by means of an NXT brick to a computer, on which the user can view the scanned image.

The iPhone-controlled house, truck, and Create robot, one of which is shown in Figure 3, demonstrated to users the capabilities of wireless communication technology as well as the robotic systems necessary for a “smart” house, off-road autonomous vehicle, and domestic autonomous vehicle. Lastly, the audio-enabled hexapod robot, which uses the Basic Stamp 2 microcontroller, servomotors, and sensors, illustrated the notion that constructing robots is within the abilities of the young attendees of the Expo.

EXHIBIT TEAM'S REFLECTIONS

Over the two expo days, the Mechatronics Mania exhibit was operated by four current and former AMPS fellows, two collaborating researchers from the Mechatronics Lab

at NYU-Poly, two Brooklyn public school teachers, and two engineering faculty. The experience was considered a positive and unique opportunity to interact with a diverse group of students interested in some aspect of science or engineering. Fellow Jennifer Haghpanah noted the beneficial result of the concentrated nature of the festival: "I believe this was one of the most life-changing experiences for me because I was able to watch a large number of students get excited about science, technology, and engineering in a short period of time."

Young visitors made lasting impressions on the fellows as well. Fellow Ryan Caeti, a high school instructor, found the experience rewarding since it allowed him to work with much younger children. In particular, he recounted interacting with a bright young student through his demonstration: "This child quizzed me on the demonstration's working and even commented on effective ways in which I could improve its design. It wasn't until a good 30 minutes later of discussing various topics of engineering, including complex topics such as the speed of sound and light, that his mother finally said that he had to leave to see other booths before the expo closed for the day. It was truly amazing how our simple, or what I believed to be simple, demonstrations touched the children who entered our exhibit."

The attending AMPS teachers also described how effectively the mechatronics-based projects engaged Expo visitors. Teacher Noam Pillischer found inspiration working with both fellows and young visitors: "Watching the work of the fellows and their interaction with the public was career changing. I was so amazed at what the fellows engineered and how into the mechatronics the crowd was that I decided to look into getting a second certification in physics. I am happy to say that in the fall I will be the physics/math teacher at my school, and I plan on using mechatronics as a tool to make physics and math more interesting."

VISITORS' IMPRESSIONS

An estimated 2500 visitors to the expo interacted with the Mechatronics Mania exhibit, and 219 of these young visitors filled out a survey distributed at the exhibit. The survey, shown in Figure 4, was designed to obtain demographic information about the participants and assess the efficacy of the Mechatronics Mania exhibit in educating visitors about mechatronics. The survey consisted of seven questions, a demographic question (Q1), a career-choice question (Q2), a series of multiple-choice mechatronics and engineering knowledge questions (Q3–Q6), and a satisfaction question (Q7). The questions were designed to be pictorial to foster accessibility for preschool visitors who may have only a limited vocabulary; see Figure 4. To engender greater participation and excitement for this activity, the survey was offered as a "puzzle" to younger visitors.



FIGURE 3 NYU-Poly student David Lopez instructs young visitors on using an iPhone to control a toy truck. (Photo courtesy of Jared Alan Frank, graduate research assistant, NYU-Poly.)

Using responses to Q1, young respondents were partitioned by school ages as follows: 10% pre-elementary, 61% elementary, 20% middle school, 7% high school, 1% post-high school students, and 1% unreported, which shows that the vast majority of respondents were very young. Career aspirations from Q2, allowing for multiple responses, are presented in Table 1. We find that a large proportion of respondents have interest in STEM and medical fields, which demonstrates a predisposition of survey respondents toward science-related fields.

Survey responses to Q3–Q7 are reported in Figure 5, where the percentage of respondents identifying each response to each question is calculated combining both expo days. Responses to Q3 show that respondents had limited exposure to mechatronics before visiting the Mechatronics Mania exhibit. More specifically, only 27% of respondents reported having heard the term "mechatronics" before their visit to the expo. We use the response to Q3 to infer that the knowledge of mechatronics devices and fundamentals used to answer Q5 and Q6 can be attributed mainly to the respondents' experiences at the Mechatronics Mania exhibit. Both Q5 and Q6 contain two correct and two incorrect responses. The two correct answers for Q5, robots featuring robotic arms, are located by approximately 70% of respondents each, with 93% identifying at least one correct response and 60% identifying both. The two correct answers for Q6, a pulley and a circuit board, are located



Dear Visitor: Thank you for visiting our exhibit! We would like to know what you think about our exhibit **Mechatronics Mania**. We will use your input to evaluate our project. Thanks for helping us!

— The AMPS Team

1. What grade are you in? _____
2. What do you want to be when you grow up? _____
3. Did you hear the word **mechatronics** before today? Circle one: YES NO
4. Circle the letter under every picture that shows an engineer.



A



B

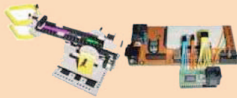


C



D

5. Circle the letter under every picture that shows a mechatronic device.



A



B



C



D

6. Circle the letter under what you need to study to be a mechatronic engineer.



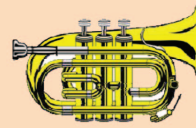
A



B



C



D

7. Circle the letter under every face that describes how **Mechatronics Mania** made you feel.



A



B



C

FIGURE 4 Survey administered to young visitors of Mechatronics Mania.

by approximately 45% and 80% of respondents, respectively, with 92% identifying at least one correct response and 34% identifying both. In contrast, the incorrect responses were erroneously identified by less than 16% of respondents in Q5 and by less than 10% in Q6. As a result, it appears that the respondents to the Mechatronics Mania exhibit had limited knowledge of mechatronics a priori and that they correctly characterized mechatronics concepts and devices after the visit.

Q4 is designed to test visitors' perception of engineering fields. The four responses are made up of two engineers,

a train operator, and a handyman. Especially since it was headed by engineers, the Mechatronics Mania exhibit team was sensitive about informing visitors about the diverse range of engineering professions. Survey results show that at least one engineer was identified by 82% of respondents, while both engineers were located by 46% of respondents. However, the persistent misconception that engineers operate trains or fix things was not entirely refuted by visiting the Mechatronics Mania exhibit, as these responses were erroneously identified by approximately 40% and 20% of respondents, respectively.

The final question Q7 explicitly investigated respondents' satisfaction with the Mechatronics Mania exhibit; this question received 82% positive responses, indicating that Mechatronics Mania successfully presented engineering as a challenging and enjoyable discipline.

We further explore the survey responses using a two-tail z-test for proportions to assess the statistical significance of the results [21]. We consider each possible answer to Q4–Q6 to be independent, and we calculate the statistical significance of differences in responses to each possible answer between the two populations corresponding to a given partition of the respondent population (see Table 2). Specifically, we consider four partitions of the respondent population by day, prior knowledge of the term mechatronics, affinity for STEM careers, and age. “Day” partitions respondents who visited the exhibit on the first versus second day of the Expo. “Mechatronics” partitions respondents who answered yes versus no to Q3. “STEM” partitions respondents who offered a STEM versus a non-STEM career to Q2. “Age” partitions respondents who were elementary school age or less versus those who were older. For each partition and possible response, Table 2 gives the probability p that the two populations come from the same distribution. Following standard practice, we assume that the differences between the populations are not statistically significant when $p \geq 0.05$ and are statistically significant when $p < 0.05$.

As evidence of the similarity of the exhibit offerings on the two expo days, the survey responses of the two populations, partitioned by day, are found not to be statistically different as seen from the data in row 1 of Table 2. This result suggests that the observed trends in responses to Q4–Q6 are consistent and that the learning resulting from the exhibit is repeatable.

When we partition the survey respondents into those who answered “Yes” and those who answered “No” to Q3 (“Mechatronics” in Table 2), as evidenced from the data in row 2, we find statistically significant difference in only one out of 12 possible answers. This result suggests that the informal learning that took place at the exhibit was able to impart sufficient mechatronics knowledge to uninitiated respondents with no prior knowledge of mechatronics. Similarly,

TABLE 1 Percent of survey responses for post-Expo-assigned categories of career choice.

Career Choice	Percentage
STEM	48.9
Medicine	11.4
Arts	6.4
Non-STEM professional	6.9
Law enforcement, government, and military	5.9
Athlete	4.1
Service	0.9
Other	3.2
Don't know	13.7

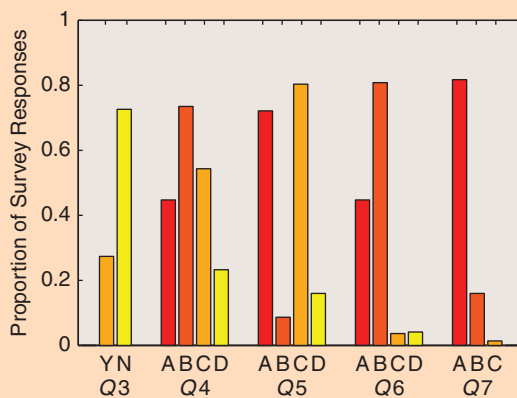


FIGURE 5 Percentage of survey respondents who identified “YES” and “NO” for Q3; A, B, C, and D for Q4, Q5, and Q6; and A, B, and C for Q7.

when we partition the survey respondents by those who provided at least one STEM career response to Q2 and those who did not (“STEM” in Table 2), as evidenced from the data in row 3, we find statistically significant differences in three out of 12 possible answers. This result indicates that

TABLE 2 Results of a z-test for proportions assessing statistical significance of differences in responses to each possible answer to questions 4, 5, and 6 based on four partitions of the respondent population. Table values less than 0.05 indicate a statistically significant difference in the selection of a given possible answer between the two populations corresponding to a partition.

	Q4A	Q4B	Q4C	Q4D	Q5A	Q5B	Q5C	Q5D	Q6A	Q6B	Q6C	Q6D
Day	0.650	0.086	0.853	0.218	0.980	0.762	0.275	0.521	0.468	0.050	0.496	0.765
Mechatronics	0.726	0.321	0.101	0.467	0.923	0.041	0.642	0.068	0.206	0.337	0.514	0.242
STEM	0.761	0.102	0.001	0.769	0.251	0.731	0.088	0.740	0.027	0.025	0.432	0.275
Age	0.796	0.000	0.101	0.072	0.009	0.669	0.289	0.560	0.061	0.001	0.023	0.242

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USA Science and Engineering Festival Expo in October 2010.**

the Mechatronics Mania exhibit was slightly more effective at reaching respondents with preexisting interest in STEM. Finally, when we partition the survey respondents into those from elementary school age and younger and those who were older ("Age" in Table 2), as evidenced from the data in row 4, we find statistically significant differences in four out of twelve possible answers. This result indicates that mechatronics learning among the respondents depends on the age of the learner, which was an expected finding of this study.

CONCLUSIONS

In this article we described Mechatronics Mania, consisting of a set of activities presented as an informal learning exhibit at the USA Science and Engineering Festival Expo in October 2010. This exhibit was developed and implemented by the members of the AMPS project, an NSF-supported GK-12 Fellows program that introduces mechatronics into central Brooklyn classrooms to enrich STEM learning. The wide variety of activities conducted at the Mechatronics Mania exhibit were outlined, and the fellows' and teachers' impressions of the exhibit were reported. Through the use of self-report survey data, we find that young respondents without prior knowledge of the term "mechatronics" successfully identified key features of this discipline after visiting the Mechatronics Mania exhibit. However, misconceptions about the profession of engineering persisted in these visitors even after participating in the exhibit's activities.

ACKNOWLEDGMENTS

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tration for enthusiastically supporting the Mechatronics Mania exhibit.

AUTHOR INFORMATION

Nicole Abaid received the B.S. and M.A. in mathematics from the University of North Carolina at Chapel Hill in 2003, and the University of Kansas, Lawrence, in 2008, respectively. She began the Ph.D. in mechanical engineering at NYU-Poly in 2008 and has served as a teaching fellow in central Brooklyn public elementary and middle schools under NYU-Poly's GK-12 project. Her research interests include collective behavior and marine systems, including aquatic animals and underwater vehicles. She is an author or coauthor of several conference and journal publications.

Carlo Yuvienco received the B.S. in chemical engineering from Cooper Union, New York, in 2005 and the M.S. in biomedical engineering from NYU-Poly in 2009. From 2005 to 2007, he worked as a research and development engineer at Pall Corporation, Port Washington, New York. He began his Ph.D. studies in biomedical engineering in 2009. Since 2008, he has served as a teaching fellow in central Brooklyn public elementary and high schools under NYU-Poly's GK-12 project. His research interests include design and application of novel biosynthetic proteins. He is an author or coauthor of several conference and journal publications.

Vikram Kapila is a professor of mechanical engineering at NYU-Poly, where he directs an NSF-funded Web-Enabled Mechatronics and Process Control Remote Laboratory, an NSF-funded Research Experience for Teachers Site in Mechatronics, and an NSF-funded GK-12 Fellows project. He has held visiting positions with the Air Force Research Laboratories in Dayton, Ohio. His research interests are in cooperative control, distributed spacecraft formation control, linear/nonlinear control, and mechatronics. He received NYU-Poly's 2002, 2008, and 2011 Jacobs Excellence in Education Award and a Distinguished Teacher Award in 2003. His research activities include three edited books, 50 journal articles and book chapters, and numerous conference papers.

Magued Iskander is a professor in the Civil Engineering Department at NYU-Poly. He is a recipient of an NSF CAREER award, Chi Epsilon (Civil Engineering Honor Society) Metropolitan District James M. Robbins Excellence in Teaching Award, NYU-Poly's Distinguished Teacher

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The President's House of Nanjing.

who discussed how to submit papers to technical journals.

SIGHTSEEING AND CLOSING CEREMONY

During the conference, the attendees were invited to visit the President's House of Nanjing. In the closing ceremony on May 22, Jianbo Su, chair of the CAA Youth Working Committee, announced that the 27th YAC will be held in 2012 in Hangzhou, Zhejiang Province, P.R. China, where it will be hosted and organized by Zhejiang University of Technology. We would like to welcome friends from all over the world to Hangzhou, China, next year.

Jingnan Liu, Baoping Wang

YAC General Chairs

Jianbo Su, Changyin Sun

Program Chairs

Shumin Fei, Hua Ye

Organizing Chairs



Tianjin University in China, and Jianbin Qiu, from Harbin Institute of Technology, presented their research on hypersonic vehicles. Xi Xu, from National University of Defense Technology in China, presented the talk "Learning Control Of Dynamic Coeffi-

cients Based on Markov Decision Processes." Qihong Chen, from Wuhan University of Technology, discussed the hybrid power supply technology of fuel cells. The last report was given by Fei Song, executive director of SCIENCE CHINA Information Sciences,

» FOCUS ON EDUCATION (continued from page 110)

Award, and Jacobs Excellence in Education Award. His research interests include geotechnical modeling with transparent soils, foundation engineering, and urban geotechnology. He has published ten books and 90 papers, and he has supervised the research activities of several school teachers and high school students.

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