ISEC 2017

7th IEEE Integrated STEM Education Conference

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Saturday, March 11, 2017

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Acknowledgment

Many thanks to Emily A. Carter, Ph.D., Gerhard R. Andlinger Professor in Energy and the Environment and Dean of SEAS, Princeton University; Andrea Mameniskis, Assistant to the Dean; and Michelle Horgan, Senior Conference and Event Manager, for your kind hospitality in hosting ISEC '17!

We also appreciate very much the contributions of the volunteer reviewers, session chairs, conference staff, and "friends of the conference." The conference benefits greatly from the gifts of your time, skills, and knowledge.

Calendar of Events

8 am – 3 pm
Registration in the Convocation Room
Speaker Preparation Room – Dean's Conference Room

8 – 11 am
Breakfast in the Convocation Room

9 am – 4 pm
Posters and Exhibits in the Convocation Room and 101 Area
Posters by K-12 Students
ANDRO Computational Solutions, LLC
Andrew Drozd and Daniel Kostelec
MathWorks: World's Leading Developer of Mathematical and Technical Computing Software
PJ Boardman and Akash Gopisetty
Start Engineering
Robert Black
UBTech Education
Howard Michel, Ph.D. (IEEE President and CEO, 2015) and Jack Wang

9 – 10 am
Keynote in FC 101
The Curiosity Effect
Kimberly Ennico Smith, Ph.D.
Research Astrophysicist
NASA Ames Research Center

10 – 10:50 am
Town Hall/UnConference in FC 101
Assessment in Integrated STEM Education
Vignesh Subbian, Ph.D., Facilitator

11 am – noon
Paper Presentations and Workshops

noon – 1 pm
Lunch in the Convocation Room

1 - 1:30 pm
Special Focus on Posters and Exhibits

1:30 – 4:30 pm
Paper Presentations and Workshops

Keynote Speaker
Kimberly Ennico Smith, Ph.D.

Dr. Kimberly Ennico Smith is a NASA research astrophysicist who loves exploration, learning, embracing inspiration and sharing authentic conversations (especially over a cup of tea) about the wonders that surround us and motivate us. Dr. Ennico was born in and grew up in New Jersey, and studied physics at the Johns Hopkins University in Baltimore, Maryland. Funded as a British Marshall Scholar, Isaac Newton Scholar, AAUW American Fellow and Amelia Earhart Fellow, she obtained a PhD in astronomy from Cambridge University, Cambridge, England.

She is multidisciplinary in her approach to space instruments, telescopes and mission concepts. She has worked on infrared airborne and space telescope cameras and spectrometers, tested detectors in laboratories and particle accelerators, designed low-cost suborbital instruments, built lunar payloads, and most recently served as deputy Project Scientist leading the calibration of the New Horizons Pluto fly-by mission.

She has written blog entries for NASA on numerous topics, actively participates in social media science communication venues, and enjoys giving school and public presentations about astronomy and space exploration, always advocating the need for a more diverse STEM community.

Abstract

This conference aims to improve how we learn through integrative project and discovery-based methods. My talk highlights areas in my experience as a scientist, and more recently working for our national space agency, NASA, where we work in teams with a "discovery-based" mindset. When you demonstrate broad curiosity, you become open to different viewpoints and ways to approach and manage situations. Sometimes working only from "what you have been trained to do" or "what you know" is not enough, especially when the rules may be changing. Increasing our openness in our learning, and sharing what we know, can lead to a more diverse and innovative community, solving problems in new ways, overcoming resistance to new ideas, and hopefully creating a dynamic and faring-forward society. Let us not kill curiosity, at any age, in any situation. Let us remind ourselves, at any time, in any circumstance, to continue to learn, to mentor, to stimulate, to engage and reconnect with that "open sense of possibility."

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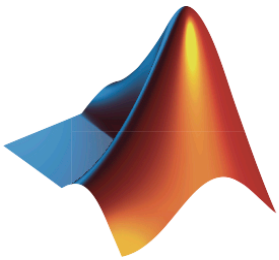

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In Memoriam

Roger Walker Amidon, Jr., a long time volunteer with the Trenton Computer Festival Steering Committee, passed on May 13, 2016. An electronics engineer and computer programmer, an innovator and entrepreneur, he made numerous meaningful contributions to the development and growth of the personal computer industry. He was also deeply involved in amateur radio as a member of ARRL, holding the call sign K2SMN for sixty years. His immediate survivors are his wife of more than 37 years, Nancy; sons David and Roger; daughter-in-law Elizabeth; and granddaughter Pearl. He is also survived by his four siblings and their families. Roger's creativity, drive, knowledge, generosity, and contributions are missed.

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FC 004 Integrated K-12 and Outreach Programs - I

Chair: Clifford Sayre (Verizon, USA)

11:00 *+Bioinformatics for Middle School Aged Children: Activities for Exposure to an Interdisciplinary Field*

Kathryn Cooper, Angela McGraw, and Deepak Khazanchi (University of Nebraska - Omaha, USA)

Recently, there has been a push for better exposure, recruitment, and training of United States adolescents to STEM (science, technology, engineering, and math) related fields. Educators are working to empower youths with early exposure to STEM topics to engage in the hard sciences in their futures. Among these topics is bioinformatics, an interdisciplinary focus with roots in computer science, molecular biology, genetics, and mathematics. Bioinformatics was most famously employed in the late 1990's with the initiation and completion of the Human Genome Project, and continues to play a role in biomedical research as data volume and veracity test the limits of our knowledge. Due to its interdisciplinary nature, however, bioinformatics requires a large learning curve. It is difficult to design programs for exposure and recruitment in bioinformatics for students below the college level, so much so that there are only a handful of activities appropriate for high school aged youths, and veritably none for middle school children. Despite this difficulty, we have created a program for bioinformatics exposure in middle school aged children and implemented a number of novel activities designed to teach basic bioinformatics concepts such as using biomedical databases, phylogeny, and sequence assembly. We implemented this program as part of a pilot program in iSTEM (Innovative, Interdisciplinary, Information Technology-Enhanced STEM), an after school program for middle school students (5th through 8th grade), and are encouraged to find that these young student participants found these activities fun, exciting, and enhanced their desire to perform similar activities in the future.

11:15 *Reforming Abstract Geometrical Ideas through 3D Printing: A Proposal for Experiential e-Making Technology in Creative Education*

Sylvia Stavridi (Library of Alexandria, Egypt)

"Abstract art" is a powerful medium of expression but simultaneously a very poor means of visual communication. In an effort to physically experiment with symbolic yet innovative thoughts or ideas in geometric, abstraction art, the researcher investigates the potential, value, and uses of building simple three-dimensional (3D) objective interpretations of reality available to touch. This paper describes the primary objectives of a one semester project-based learning proposal involving Alexandrian middle-school students or young learners. The project integrates 3D modeling/printing into creative activities so middle-school students or young learners can learn the functional aspects of abstract geometric forms and compositions and how to design and print 3D models. Drawing on the literature that explores the true potential of the technology that transfers 3D digital modeling to tactile solid objects by building them up in layers, the paper discusses the need for future research to develop artistic understanding of 3D printing and how it affects the physical reality of the explored forms and materials. Given the feasibility of 3D printing technologies and how these developments continue to expand, the researcher notes that the use of 3D printing geometric art models can be a powerful supplement for creating abstract geometrical design with touch input. 3D printers are adding new flexible materials that engage the imagination of middle-school students or young learners and allows them to create or interact with visual representations of concepts and turn them into a tangible reality where 'seeing' and 'making' intersect, and where possibility becomes reality.

11:30 *Music as the Heuristic Path to Signal Processing Careers*

S. Nils Straatveit and Andrew Straatveit (SeeSignals, USA)

Our country's asymmetrical technical advantage requires more science and engineering students. However, interest in STEM careers is declining. Many students drop out of STEM majors because introductory courses are often too difficult or too abstract. In trying to address the problem some say we should require students to take more STEM, but that is like stuffing them with more broccoli. We need a new very appetizing recipe. We must entice, interest, and motivate highly qualified students to go into STEM. We propose to engage and motivate an untapped resource, namely music students; who typically turn away from STEM careers. In the past 15 years, enrollment in Computer Science Advanced Placement test grew by just 12% while Music Theory AP grew by 362%." Very interesting and foreboding. We see music students being enticed by their passion to participate in "Music as the Student's Heuristic Path to Signal Processing Careers." Students of the arts continue to outperform their non-arts peers on the SAT. So music students are very smart as well as disciplined, task oriented, work well in teams, have self-confidence, and good communication skills. To capitalize on these valuable attributes, we are creating workshops that have math formula visualizations for students to manipulate but in an enticing music

heuristic. Our first workshop called "Harmonizing Hamsters" is a game in which a player adjusts the singing of two hamsters to create harmony. The note and frequency of each hamster's song is displayed in the formula to show when harmonics occur. The lesson is that harmonics are realized by doubling the fundamental's frequency. The note to frequency connection expands the student's signal processing vocabulary. When a harmony is achieved, the player is rewarded by the hamsters singing.

11:45 *Bringing the M Out in STEM: Revising an Engineering Task*

Stephanie Purington, Alicia Gonzales, and Elizabeth McEneaney (University of Massachusetts - Amherst, USA)

This paper describes the revision of an engineering design task to better integrate mathematics content and practices. After studying engineering and science inquiry group tasks, we found that mathematics content in the tasks was often hidden to students and could be made more explicit. We attempted to bridge the link between practices used with mathematics and practices used with science and engineering. We altered a Pill Coating engineering design task to promote modeling with mathematics. We realize that implementation of integrated STEM tasks can be difficult. Due to this difficulty, we provide some suggestions and implications for teachers. These suggestions include adding proper scaffolding and prompting discussions.

FC 005 Computing in STEM Education

Chair: Jeffrey Beck (Quality & Compliance Solutions, USA)

11:00 *Project-Based Learning in a Probabilistic Analysis Course in the CS Curriculum*

Abdelrahman Hosny and Swapna S. Gokhale (University of Connecticut, USA)

This paper presents our experience in using a project-based learning approach in a senior-level class, which is not a traditional candidate for learning through projects in the CS curriculum. The objective of this class was to expose students to computer science applications of probabilistic analysis and stochastic processes. The class project expected the students to apply the concepts of Markov Chains constructed during in-class lectures to develop an understanding of the ranking algorithms used by the widely popular search giant, Google. These ranking algorithms sort web pages according to their relevance to a search query. Based on their understanding, the students were also expected to identify and document some strategies that can be employed by owners to improve the rank of their web sites. We found that our project, that guided the students through the four phases of project-based learning, led to unprecedented outcomes in the students' understanding of the subject. Not only did they apply the in-class knowledge to cultivate an understanding of a real-world problem and its solution, but they were also able to project strategies that were external to the class material. Our observations suggest that a project-based approach can offer an integrated learning environment to boost students' understanding even in those CS courses that conventionally may not employ projects.

11:15 *Designing a Community Aware Virtual Learning Infrastructure for STEM*

Mark Allison and Stephen W Turner (University of Michigan-Flint, USA)

Universities are striving to increase the magnitude and engagement of STEM learners, while keeping pace with their technology needs. In seeking solutions, the research community has offered approaches on both the learning technology and STEM pedagogy fronts. These approaches are mostly being developed in parallel with negligible empirical studies as to the integration of applied learning theory and delivery technology. To compound this challenge there exists the critical component of developing diversity within the STEM workforce inclusive of Underrepresented Groups. In order to address the latter concern from the standpoint of the academy, longitudinal studies propose the following as intervening strategies: (1) Augmented Pedagogical Models; (2) Early K12 Outreach; (3) Academic and Social Support, and (4) Learning Communities. Abstract--- This paper proposes a set of the prime concerns and a design science research methodology grounding for a cloud based infrastructure capable of supporting the aforementioned strategies. Specifically the infrastructure will be designed modularly to facilitate a virtual collaborative environment inclusive of tutoring, experiential learning, and K12 inclusion.

11:30 *Virtual Reality Instructional Modules for Introductory Programming Courses*

James Stigall, Jr. and Sharad Sharma (Bowie State University, USA)

Undergraduate students may find computer science to be a tough subject to learn. Students might not grasp concepts with traditional teaching methods, even if they are ideal. Likewise, instructors could also find computer

science hard to teach. This predicament could lead to poor academic performance for students as well as students not possessing adequate programming skills needed for software development careers. Gamification is the application of game-like elements to non-gaming activities used to encourage people to participate in those activities and achieve specific goals. Emerging research proves the effectiveness of gamification in academia, especially in the computer science realm. Thus, we have built two gaming modules for teaching object-oriented programming (OOP) and binary search. This paper discusses the design, development, and testing of virtual reality instructional (VRI) modules based on gaming metaphor. Constructivism and usability were considered while developing them. A user study found that about 75% of undergraduate students found the OOP module was easy to use and about 92% of them thought that it is effective at helping them learn OOP.

11:45 + *Incorporating Music Into an Introductory College Level Programming Course for Non-Majors*

Tacksoo Im (Georgia Gwinnett College, USA); Jason Freeman (Georgia Institute of Technology, USA); Sebastien Siva (Georgia Gwinnett College, USA); Shelly Engelman and Morgan Miller (The Findings Group, LLC, USA); Brandi Villa (Sagefox Consulting Group, USA); and Tom McKlin (The Findings Group, USA)

STEAM-based courses are increasingly becoming popular in introductory programming courses but not many of these efforts focus on non-major undergraduate students and less is known about its effectiveness with career-bound students at the collegiate level. This paper describes our results and the lessons learned in teaching and implementing an EarSketch based introductory programming course for non-majors. EarSketch is a computational music learning platform that has been used successfully at the high-school level to introduce students to programming. We have adapted the EarSketch curriculum to satisfy the requirements of an undergraduate level introductory programming course. We have deployed the curriculum at Georgia Gwinnett College starting in Spring 2016 with the goal of observing improvements in content knowledge and attitudes towards computing. We have observed statistically significant improvements in the sections using EarSketch. Although more data is required to confirm our results, we argue that the EarSketch based curriculum engages students positively in the field of computing.

FC 006 Integration in Higher Education I

Chair: Zhigang Zhu (The City College of City University of New York, USA)

11:00 *Improvement of Student Learning Experience via an Interdisciplinary Undergraduate Research Project with Top-down Design and Bottom-up Implementation*

Wookwon Lee and Nicholas B. Conklin (Gannon University, USA)

Engineering curricula generally integrate design-oriented courses at various levels of progression in a curriculum. However, students seem to still lack the ability to properly carry out engineering design work when trained only within a curriculum. In an effort to complement the design-oriented courses in electrical engineering and their laboratory exercises, an interdisciplinary undergraduate research project administered in an extracurricular setting is examined to improve student learning experience and technical competency. With recognition of the importance of a top-down design approach, a complex design project is conceived in a top-down approach but also to better facilitate student's acquisition of hands-on engineering skills, a strategy of comprehensive bottom-up implementation is integrated into the project activities to successfully complete the project. Our observations and recent survey results show that students benefit substantially from the heavy bottom-up implementation activities when the project objectives and requirements are clearly defined as in the typical top-down design.

11:15 *CCNY Joint Senior Design Program in Assistive Technology Across the Department Boundaries*

Zhigang Zhu and Jizhong Xiao (The City College of City University of New York, USA)

We have built a cross-department joint senior design program at The City College of New York (CCNY) for undergraduate seniors majoring in Computer Science (CS), Computer Engineering (CpE) and Electrical Engineering (EE), to develop assistive technologies for people in need. These include: multimodal, passive and unobtrusive techniques for helping visually impaired people to achieve independent travel in unfamiliar environments; smart house systems and mobile apps for improving the quality of life of elderly and people with disabilities (e.g., with Autism Spectrum Disorder); and sensing technologies for health monitoring and rehabilitation. For evaluating the designs by students, we also have faculty and students from the Psychology Department involved in our team projects. The joint senior design course builds on our existing capstone design

course structure in the CS and EE Departments, which also jointly manage the CpE program. We have obtained multiple grants/awards from the National Science Foundation, the NYS Industries for Disabilities and VentureWell to run this course with cross-disciplinary collaboration, learning-by-doing learning experience, student-led class schedules, team building practices, user-in-the-loop development and entrepreneurship training, and oral/writing presentation practices.

11:30 *An Integrated Electric Power Curriculum: From High School to Doctoral Research*

Ned Mohan, William Robbins, and Bruce Wollenberg (University of Minnesota, USA)

This paper describes the work in progress for education in Electric Power, Control and Energy Systems (EPCES) at undergraduate and graduate levels, initially commencing in high schools. Further, the paper describes a methodology to build a robust pipeline of high school students by choosing electric power/control/energy as a field of study as undergraduates. This paper describes the graduate courses developed and being developed. This paper is based on previous work, and provides the updates since the results reported therein. Resulting from this process are students having the flexibility upon graduation to work in industry or to go on to graduate school and doctoral research, or to work in a field different than power/control/energy.

11:45 *A Novel STEAM Approach: Using Cinematic Meditation Exercises to Motivate Students and Predict Performance in an Engineering Class*

Ravi Rao (Fairleigh Dickinson University)

Given the high drop-out rates of students from colleges in USA, including STEM fields, there is a national imperative to address this issue with all possible means. The role of technology is cited as being increasingly important in tackling this problem. Universities are pushed towards providing students with personalized attention and timely academic feedback, but need to deploy technology to support this at scale. At the same time, intrinsic student motivation also plays an enormous role in success. It is important for educators to present course material in an engaging way that captures student interest and imagination. A major challenge facing students is that it may take a few weeks of attending a course before they realize they may be either uninterested in the course, or that it is too difficult for them. Typically, the students who earn poor mid-semester grades are more likely to get an F grade or drop out of the course. We explore the use of cinematic meditation both as a tool to improve student interest in engineering, and as an early quantitative predictor for student success in a freshman course. Cinematic meditation involves watching a film with specific pre-defined questions that a viewer needs to focus on. Students are asked to complete an extra-credit assignment involving written answers to these questions. We describe a simple mechanism for providing early feedback to students, instructors and administrators. This involves a cinematic meditation exercise which is given early in a course. We found that a simple metric based on word-length of an essay has a moderate correlation with the mid-term grade. Furthermore, a failure to submit this essay was correlated with low grades. This approach lends itself to automation as it is easier to perform this analysis on text documents rather than hand-written submissions that involve drawings.

FC 007 STEM + Entrepreneurship

Chair: Ariel Anders (MIT and CSAIL, USA)

11:00 *From Idea to Prototype: Introducing Students to Entrepreneurship*

Colin Reagle, Viviana Maggioni, Mihai Boicu, Massimiliano Albanese, Maheshkumar Joshi, Dann Sklarew, and Nathalia Peixoto (George Mason University, USA)

We describe here results from a semester-long class taught by seven faculty at George Mason University, aimed at providing resources to engage students in idea generation, engineering cycle development, and finally elaboration of a business plan. This is intended to alleviate a perceived lack of access for science and engineering students to methods for commercializing their ideas. Undergraduate and graduate students are often left with unfinished class projects that do not turn into prototype or into products. Here we attempt to bridge that gap (often referred to as the "valley of death"). We have recruited students with ideas for products as well as students with varied expertise in engineering and scientific fields. We have then formalized the engagement through the offering of a class that met once every other week over four months. After the class each team underwent a one-week intensive bootcamp for a final demonstration and presentation of their product and business plan. Throughout the semester the groups received micro-grants and used the financial support to acquire materials to prototype several iterations of their ideas. In this paper we present data from two successful groups (out of five groups who took the class, three completed, and two continued with their product beyond the class). We also discuss strategies to engage students, to form groups, to provide technical support, and to deliver content in a non-traditional environment, with

students not only from different backgrounds (sociology, civil engineering, computer sciences) but also from first year college students to graduate level.

11:15 *Combining STEM and Business Entrepreneurship for Sustaining STEM-Readiness*

Pradeep Nair, Jidong Huang, John Jackson, and Amy Cox-Petersen (California State University Fullerton, USA)

Sustaining interest in STEM subjects throughout the academic career is often the key to a successful STEM career. Maintaining a "STEM-interested" student body can potentially have significant long-term implications for the success of the future STEM workforce. In many cases, students who initially like STEM subjects begin to lose interest in STEM subjects during middle school years. This work-in-progress paper explores the findings of the second year of STEM-Inc, an afterschool program in junior high schools that combines team-based, real-world engineering and computer science projects with business entrepreneurship concepts. One of the important goals of the program is to sustain student interest in STEM subjects and make them aware of STEM careers. Participants are supervised by college student mentors in partnership with school teachers. Traditionally underrepresented students form a significant component of STEM-Inc. While interest in STEM activities, team-work and entrepreneurial confidence for students were positively influenced in year 2, no significant improvements were observed in STEM skills and interest in STEM fields. STEM-Inc also had considerable positive influences on college student mentors and school teachers. Two mentors reported that they are considering a career in STEM education after their involvement in STEM-Inc. School teachers reported being confident in the inclusion of engineering examples and the design process in their math and science courses.

11:30 *Workshop: STEM Education in a Global Society*

Donna Schaeffer (Marymount University, USA) and Patrick Olson (National University, USA)

The learning objectives of this workshop include increasing awareness of global issues related to the STEM fields. Graduates from any level of STEM education must be prepared to collaborate in a global society. Emerging technologies, such as drones, 3D printing, autonomous cars, and others yield ethical issues that are complex, and made even more complex by the global context in which education, commerce and work, and even play are now occurring. We will present lesson plans that can be adapted to most levels of STEM education and give participants a chance to interact with one another and debate topics related to these emerging technologies. The target audience includes educators who teach about technology and who want to introduce globalization into their courses, or those who have successfully integrated globalization into their curriculum and want to share their strategies with others. (Workshop will last until 12:15 pm)

FC 008 Early STEM Interventions for Children/K-5

Chair: Nagi Naganathan (Broadcom, USA)

11:00 *Creation of an Elementary School STEM Lab*

Kathleen Conezio (St. Louis School, USA)

This paper describes the creation of a STEM lab in a small elementary school level during the past two years. Examples of investigations that have been developed and taught in alignment with the Next Generation Science Standards are provided. Investigations that are new for this school year are also described to demonstrate the on-going nature of the creation of STEM curriculum at this level. In an effort to stress the integrated nature of children's learning, this paper presents science curriculum topics that have been integrated with various other curricular domains such as English Language Arts, Social Studies, Art and Music. These particular activities have been extremely successful in demonstrating the significance of science in the everyday lives of people. The unique nature of STEM laboratory teaching has been expanded to the student families through take-home science investigations as well as parent-child STEM activities after school in the lab. The impact on both student learning and student attitude towards science education is explained.

11:15 *Design of STEM Activities and Study of Their Motivation Efficacy*

Diana Gaitan-Leon and Mariana Tafur-Arciniegas (Universidad de los Andes, Colombia)

Perception towards Science, Technology, Engineering and Math was studied in children, before and after four activities were done. The topics of the activities were locomotive system, circulatory system and nervous system. Each topic was introduced with questions related to the students' daily life, then animated videos were shown, and tasks and challenges were done by the participants. At the end of each session, conclusions and reminders were

obtained with complementary activities. The kids took active part in the process and approached the knowledge in different forms. Quantitative and qualitative data were acquired through a survey, before and after the activities. Quantitative data were analyzed showing significant differences and trends in better attitude and improved self-confidence towards the disciplines. Analyses were done for gender and grade for each question and for the constructs. Qualitative data was quantified showing the importance of the students' context in their education and also, the value of this kind of activities in low-income students.

11:30 *STEM Activities for Toddlers*

Vyshnavi Malathi Ramesh (Independent Reseacher, India)

STEM activities are activities that promote learning in Science, Technology, Engineering, and Mathematics. They claim to help children work towards careers in these areas. They promote cognitive and psychomotor development in children, and assist in developing their meta-cognitive knowledge. While typical STEM activities for young children are categorized into broad categories of robotics, physics and astronomy and are geared towards children aged 3+, STEM activities exist for children as young as one year. The following paper identifies a set of STEM activities geared towards toddlers, the reasons why these activities qualify as STEM activities, and subsequently identifies competencies acquired by the child while completing these activities, and the sub-competencies associated with each competency. The cognitive, psychomotor and affective skills promoted by these activities are also identified and subsequently the difficulty of different competencies associated with the same activity are compared. The activities chosen for discussion are blocks and shape sorters.

11:45 *From Classroom Arduinos to Missions on Mars: Making STEM Education Accessible and Effective Through Remotely Operated Robotics*

Jonathan West (Southwestern Indian Polytechnic Institute & University of New Mexico, USA)

Computer programming skills are a critical necessity for today's students, but maintaining student interest in programming and engineering courses is challenging unless the theory is accompanied by engaging, hands-on applications. Additionally, many schools, especially those in underprivileged areas, lack the resources and personnel to develop or implement such applications. The Southwestern Indian Polytechnic Institute (SIPI), through the support of a NASA grant, has developed an integrated teaching program where students from middle school through the college levels can learn programming and robotic design from the most basic introductory level to advanced embedded computing, hardware and webpage design at little or no cost to the participating schools and with minimum burden to the teachers. The centerpiece of the program is the indoor "Mars Yard" which is a SIPI facility that allows remote operation of robots in an indoor environment to simulate remote space missions. Beginning with simple Arduino-based robot kits, students in the middle and high school levels are introduced to programming and robotics using an easy to follow curriculum. As they advance, students can remotely access the Mars Yard and perform pre-determined missions on real or simulated rovers. At the advanced high-school and college level, the students proceed to design, build, program and test their own robots and sensors and develop custom missions. The educational platform described in this paper is being implemented at SIPI and affiliated local high schools with tremendous results.

FC 004 Integrated K-12 and Outreach Programs II

Chairs: Jeffrey Beck (Quality & Compliance Solutions, USA) and Vignesh Subbian (University of Arizona, USA)

1:30 +Comparing High-School Students' Interest and Understanding in Individual versus Integrated Biology and Engineering Topics

Deeksha Seth (Drexel University, USA); Mike Kaczmarczik and Mariah Romaninsky (Academy of Natural Sciences of Drexel University, USA); and James Tangorra (Drexel University, USA)

Despite the increased interest from educators to make science, technology, engineering, and mathematics (STEM) education more connected and integrated, there is little research on how to best do it. Although some studies suggest that integrated STEM education can have a positive impact on student learning outcomes, the studies contain some gaps and inconsistencies that make it challenging to implement or assess integrated STEM educational methods or programs. In this paper, we present and assess one way of integrating biology and engineering. The objective of this study was to begin assessing high-school students' interest and understanding in a few biology and engineering topics, as well as topics that integrate those same biology and engineering topics. A short survey was developed and administered with a small sample population (N = 27), and a short focus group study was conducted with 14 high-school students. The students were given a list of 18 topics, 6 of which were natural science topics (i.e. biology), 6 were applied science topics (i.e. engineering), and 6 topics integrated the natural and applied science topics. Students were asked to report their level of interest and understanding for each of the topics. The mean values were computed for each topic, and a two-way ANOVA analysis was done to determine if the responses for different category of topics were significantly different. Results suggested that, in general, students interest in integrated biology and engineering topics, greatly depended on the way the topic was presented. Some interesting relations between natural science, applied science, and integrated topics, as well as between students' interest and understanding were observed and are presented here.

1:45 *Hands-on Workshop: Using MATLAB for STEM Learning*

Akash Gopisetty (MathWorks, USA)

MATLAB is used in more than 5000 universities and schools world-wide. MATLAB combines math, graphics, and programming in an environment that is easy to use and get started. It is used by millions of engineers and scientists to solve challenging real world problems. In this workshop, you will learn how you can use MATLAB to accelerate the pace of STEM discovery and learning. From teaching mathematics, physics and engineering in schools, to robotics in student competitions and enriching STEM outreach efforts.

3:15 *Workshop: Modeling the Engineering Design Process in Your Classroom – An Improved Oil Spill Activity*

Miancheng Guo, Julie Robinson; Elizabeth McEneaney, and Martina Nieswandt (University of Massachusetts - Amherst, USA)

This teacher professional development workshop will introduce participants to design-based science (DBS) - an integrative STEM pedagogical approach - by engaging them in small group work in a hands-on oil spill cleanup activity. In the first part of this session, the presenters will make a concise presentation introducing the notions of DBS and engineering design. In the second part, participants, acting as middle/high school students, will use inexpensive and accessible materials to design a system for oil spill cleanup. To do this, they will follow the steps of the engineering design process and consider several real-life constraints (e.g., their solution's cost and environmental impact) and make tradeoffs between these constraints and the performance of their solutions. Moreover, they will be encouraged to engage in multiple iterations of their design cycle so as to improve their solutions. In the last part of this session, the participants will reflect on and discuss important topics including: (1) how they have experienced small group work and the engineering design process, how they have learned some important engineering concepts (e.g., constraint), and how they have constructed their relevant scientific knowledge (e.g., ecosystem dynamics); (2) how they can use this activity as a model for their own DBS teaching. Upon completion of this workshop, participants will be able to: • Understand that according to NGSS engineering design has become a part of science education and has the same importance as scientific inquiry • Understand and describe the engineering design process • Understand some key engineering concepts, such as constraint, tradeoff and optimization • Understand DBS as an integrated STEM pedagogical approach, that is, engineering design can be applied in the science classroom so students learn knowledge and practices in both science and engineering • Use this activity as a model for future DBS instructional design

4:00 *+Quantifying K-12 and College Student Learning Outcomes of STEM Guitar Building*

Sean Hauze (San Diego State University & Claremont Graduate University, USA); Debbie French (Wilkes University, USA); Imelda Castañeda-Emenaker (University of Cincinnati, USA); Mark French (Purdue University, USA); and Thomas Singer (Sinclair Community College, USA)

There is a national initiative to incorporate integrated science, technology, engineering, and math (STEM) in K-16 classrooms. This study quantified student learning outcomes related project-based STEM guitar building curriculum implemented in institutions serving students grades 6-8, 9-12, and at the college level. Faculty participants were provided with tools and training needed to implement STEM guitar building curriculum. The curriculum included students building guitars as well as completing pre- and post-assessments that tested their knowledge of 12 modular learning activity skills, such as electronics, scale length, and guitar geometry. These skills align with the Common Core math standards and the Next Generation Science Standards. The data collected include pre- and post-assessment from 769 students in 15 states. Analysis of the pre- and post-assessment scores using the Wilcoxon signed ranks test demonstrated a significant increase in scores for each of the 12 MLAs; each post-assessment score was statistically significantly higher than the corresponding pre-assessment score at the $p < .05$ level. Overall, the STEM guitar building curriculum resulted in improvements in pre- and post-assessment scores measuring STEM related concepts for this group of 769 students.

FC 005 Integration in Higher Education II

Chair: Henry Griffith (Michigan State University, USA)

1:30 *Designing and Deploying EECS Hardware Grading in Online Automated Teaching Platforms*

Joseph D. Steinmeyer (Massachusetts Institute of Technology, USA)

Incorporating hardware such as circuits with elements like sensors and actuators into online education platforms presents significant challenges, particularly when the learner and educator are not in the same location as one another. Open-ended design questions, can increase the challenges associated with assessment further still. In the past two years, we have been experimenting with ways to integrate varying degrees of automated grading and assessment for the hardware (circuits) designed and constructed by students in EECS-focused coursework at the secondary and undergraduate level, mostly in the context of embedded systems and controls using platforms like the Arduino/Teensy and Raspberry Pi. This work-in-progress paper briefly covers some ways we have gone about designing problems for hardware that can be assessed by online graders, lists a few example problem structures from several courses run over the past several years, and where we intend to take this work in the future.

1:45 *Integration of an Intelligent Tutoring Software Within an Accelerated Engineering Mathematics Course*

Henry Griffith (Michigan State University, USA) and Angela Griffith (Wright State University, USA)

Innovations aimed at eliminating mathematics-related bottlenecks in STEM curricula have received significant attention in the literature. Of these efforts, approaches offering alternative pathways through the developmental and pre-calculus course sequences are especially promising for improving access for underprepared students. The research described herein describes the integration of an Intelligent Tutoring Software (ALEKS - Prep for Calculus) within a discipline-specific accelerated remedial mathematics course taught in the College of Engineering and Computer Science at Wright State University. Namely, comparative outcomes from a controlled analysis involving two sections of the course differing only in the utilization of the ALEKS software module are described herein. Students in the experimental group experienced an average ALEKS placement score improvement of 27.00%, compared to 19.07% in the control group. This effect was especially pronounced for students entering the course at the developmental mathematics level.

2:00 *Workshop: A Connection System of Learning: How to Transition from Traditional Lecture-Style Teaching to More Active Learning Methods in the Classroom*

Gbetonmasse Somasse (Worcester Polytechnic Institute, USA)

By the end of this session, participants should be able to - Discuss the importance of active learning methods in helping students connect their prior knowledge to new concepts and skills - Understand the key components of the connection system before, during, and after a class meeting. - Design learning-activities that may help the students make a three-way connection (to the material, their peers, and the instructors) to deepen their understanding of a sample concept - Learn about tips and tools to deals with some of the challenges that may arise when implementing this connection system of learning. Target audience: - Faculty and Teachers, who are willing to

undertake more active and student-centered learning methods in their classroom Overview: The connection system of learning is an instructional strategy that combines several features of a flipped classroom, collaborative learning, corrective teaching, and continuous assessment. It allows students to connect appropriately and seamlessly to all the resources available to them and receive the appropriate support to deepen their understanding and application of the material. The strategy is designed to facilitate, for both the instructor and the student, a smoother transition from traditional lectures to more active and student-centered approaches of learning. This interactive workshop will provide information about practical steps and tools for more engineering educators to transition smoothly from traditional lecture-style teaching to more active and student-centered learning methods. Participants will engage with the three levels of the system. They allows learners to connect appropriately and seamlessly to the resources and support they need to deepen their learning of the material: self-connection with the material, connection with peers, and connection with the instructor. The presenter of the workshop will show some examples of learning activities and students' sample work and feedback on the effectiveness of the method.

3:30 *Flipped Classroom in Technology Courses - Impact on Personal Efficacy and Perception Based on Learning Style Preferences*

Muhammad Safeer Khan and Mohamed Ibrahim (Arkansas Tech University, USA)

This paper reports results of a longitudinal study to investigate the impact of flipped classroom teaching strategy in college level technology courses. A within-subjects experiment design approach is used to assess self-efficacy and perception based on learning style preferences. To compare the effectiveness of flipped based (FB) classroom with that of traditional lecture based (LB) approach, selected topics were taught using the two methods. The topic of "learning with technology in special education" was taught using LB method. The FB method was used to teach four topics: Technology tools, hypermedia tools, distance teaching/learning and role of the internet and web-based learning activities on teaching. The learning materials in the flipped teaching method included videos, post-tests and surveys. These were made available online to the students using Blackboard course content. The results show that flipped classroom approach made a statistically significant difference to the self-efficacy. The data analysis also gives insights into students' perception of learning style preferences. A survey of students was conducted to assess their personal perceptions of FB method. The students overwhelmingly favored use of FB teaching strategy compared to the LB approach because it promoted collaboration and hands-on activities during class time. The findings from this study can be used to implement FB teaching approach in other college level technology and engineering courses.

3:45 *Radio Sloyd: An Amateur Radio Approach to the University-Level Critical Thinking and Writing Class*

Kristina Collins, Sarah Bania-Dobyns, David Kazdan, Nathaniel Vishner, and Andrew Hennessy (Case Western Reserve University, USA)

This paper outlines the use of amateur radio in teaching a general education writing seminar in Case Western Reserve University's SAGES program. The paper outlines the educational philosophy of sloyd, then presents a review of amateur radio activities in terms of their cross-curricular potential. This is followed by an overview of the course, which begins by presenting the earliest means of communication over a distance - horns and drums, couriers and smoke signals - and continues into the developments of postal systems and newspapers, optical semaphores, electrical telegraphy and undersea cables, radiotelegraphy, broadcast radio, television, the Internet, and space communication. We examine the issues in each of engineering and content regulation, and of censorship. The censorship issues are presented and discussed including both governmental and voluntary or market-based forms. We conclude with a summary of how critical and con- textual writing are integrated into the course, including a discussion of writing assignments and writing-to-learn strategies.

4:00 *Quality of Small Group Work and Learning Outcomes in Design-Based Science*

Elizabeth McEneaney (University of Massachusetts - Amherst, USA)

This research posits that high quality small group work demands collective construction of a "triple problem solving space" such that engagement occurs along cognitive, social/relational as well as affective dimensions. This framework builds on preliminary work by Teasley and Roschelle as well as Barron. Pre- and post- survey data and learning outcomes were gathered from introductory biology classes in the northeast of the United States in which small groups of students worked on 3 engineering design tasks (Oil spill clean up, heart valve design, and pill coating). Results were based on 107 students in 27 groups, and highlight the particular role of group affect on learning outcomes.

FC 006 Inclusive STEM Outreach Programs

Chair: Nagi Naganathan (Broadcom, USA)

1:30 *Exposing Girls to Computer Science: Does the All-Girl Model Really Work?*

Shahnaz Kamberi (Stratford University, USA)

This case study is about the introduction of computer science to girls in an all-girl environment. Due to the lack of women in technology, many efforts are being made to expose girls to computer programming at an early age. Code camp organizers are using the all-girl model to help put participants more at ease and boost their computing confidence. High computer self-efficacy leads to studying computer science, while the stereotypical views of coding as a male subject and lack of ability in girls hinder women from pursuing CS degrees. For this study, a local Northern Virginia University offered two Java programming summer code camps in the summer of 2016, one course as an all-girl class and the other as a co-ed environment. A total of 19 girls participated and submitted post-workshop survey responses. In this paper, we explore the questionnaire differences in response between the girls within the two groups. The implications of introducing computer science to girls in a single-sex setting and its effect on girls' view of CS and computer self-efficacy are also discussed.

1:45 *Workshop: After-School Outreach Program Promoting STEM Education for Young Girls*

Rajneeta Basantkumar, Madhuri Marripelly, Madeline Zimmerman, Robin Ceasar and Shamima Afroz (Northrop Grumman, USA)

The objective is to involve corporate professionals with STEM backgrounds to discuss "how to" positively influence and identify the most effective way to reach underrepresented young girls through after-school STEM mentoring programs. Inspiring and cultivating these females in STEM while motivating, guiding, and using interactive education is extremely important. Early exposure and development nurture suppressed STEM interests which could potentially blossom. Methods used in our after-school outreach program are *Discussion of tools for gender equality and dialog about real-world career opportunities in STEM *Introduce different STEM professionals to provide examples of diversity within the field and ability to transition into a variety of roles with a STEM education *Simulate STEM careers and the available career choices *Reinforce the variability in a STEM career with hands-on activities *Visit corporate facilities

3:30 *Strategies to Address Major Obstacles to STEM-Based Education*

Melvin Goodwin, III, James Whitehair, Jacqueline G Healy and Kristen Jacksa (Laing Middle School of Science and Technology, USA)

Efforts to establish STEM-infused instruction often encounter obstacles related to standardized testing and educator buy-in. This work-in-progress paper describes two initiatives that have been implemented to address these obstacles, as part of a Whole-School STEM initiative at a middle school in Mount Pleasant, SC: partnerships with local manufacturing and engineering businesses, and a school-wide emphasis on student-centered learning enhanced by frequent and diverse use of STEM tools. Examples are provided of STEM-infused, student-centered activities in mathematics, science, English language arts, and social studies. Preliminary results and lessons learned are discussed to assist other programs that may wish to use similar strategies in support of STEM education initiatives.

3:45 *A Conceptual Model of Integrated STEM Education in K-12: A Case Study in Hong Kong Curriculum*

Gary K. W. Wong (The University of Hong Kong, Hong Kong) and John Huen (STEM Academy Hong Kong, Hong Kong)

Unlike traditional education experiences in which students' focus on individual subject areas separate from other subject areas, STEM education emphasizes on combining different subject areas in a way that integrates them together, connecting different disciplines together, and relating them to each other in a practical and coherent manner. STEM education has become such a global trend that an increasingly amount of countries have realized that humanity's future will be built on our capacity for innovation, invention, and creative problem solving. To implement STEM education in schools, many countries have tried a variety of different strategies. The situation is no different in Hong Kong. There is a distinct lack of a coherent understanding of STEM education and on how to implement STEM courses inside of the curriculums. This paper will establish and propose a framework to provide concrete references and examples to schools in Hong Kong for integrating STEM courses into their curriculums. This paper will also discuss a variety of suggestions related to STEM education; including the development and training of educational professionals will be discussed.

4:00 *High School Students' Academic Engagement and Achievement in Design-Based Science: A Gender Perspective and a Methodological Perspective*

Miancheng Guo, Elizabeth McEneaney, and Martina Nieswandt (University of Massachusetts - Amherst, USA)

The purpose of this paper is twofold. First, it explores the relationship between gender grouping in small group work in design-based science (DBS) in high school biology and female students' academic engagement in their DBS activity and the relationship between gender grouping and female students' achievement in both biology and engineering. Second, it presents a mixed methods approach to video data analysis by introducing how the researchers analyzed student engagement in the engineering design process by integrating a quantitative data analysis technique called sequence analysis and a qualitative data analysis technique called elaborated running records. Preliminary findings are reported.

FC 007 Community-Based Outreach and Pre-College Initiatives

Chair: Clifford Sayre (Verizon, USA)

1:30 *Rebuilding Smart and Diverse Communities of Interest through STEAM Immersion Learning*

Andrew L Drozd (The Project Fibonacci™ Foundation, Inc. & c/o ANDRO Computational Solutions, LLC, USA)

A STEAM-based approach to education is presented that encompasses science, technology, engineering, and math (STEM), with the addition of "the Arts" as a means of reversing continuing declines in science, math, and reading scores in U.S. secondary schools and to better prepare future STEAM scholars and professionals. This is despite the significant emphasis U.S. schools have placed on STEM curricula for nearly the past 20 years. The 2014 New York State Department of Labor report states, the President's Council of Advisors on Science and Technology (PCAST) has indicated that the United States needs at least one million more STEM workers than is currently available. The report also cites that 75 percent of students who graduate with a STEM-related degree do not take STEM jobs; however, the need for STEM careers is 2.5 times higher than other fields within New York State. A case study of Project FibonacciTM is presented whose approach is one of immersive learning that emphasizes math within a STEAM context, holding focused STEAM educational forums, and establishing centers of excellence in STEAM education. This may offer additional benefits beyond traditional STEM-only approaches. There is an upward trend towards STEAM-focused curricula driven by the decline in academic scores, which provides more challenges for our youth to compete in the global workforce; and recognizing that STEAM builds upon math as the interconnection between the science and art disciplines, thus expanding career opportunities and experience that ensure a well-rounded citizenry. We are rediscovering the need for balancing the cognitive and logical sides of the brain with the creative force to engender an agile, growth-driven nationwide community.

1:45 *Workshop: Learn How to Incorporate Collaborative Project-Based Learning in Middle School Math & Science Using Inclined Planes*

David McGillan, Kenneth Jones and Aliza Boyer (Salvadori Center, USA)

Use buildings, bridges, skateparks, etc. to bring STEAM to life while teaching critical thinking, collaboration, creative problem solving. Participants engage in a project-based exercise similar to students in their classrooms. We use an inclined plane exercise from our middle school Skateparks curriculum to analyze force. Participants hypothesize which method requires the least force to lift an object. Work collaboratively in small groups, they build and test a 3-part experiment, record findings, and draw conclusions. Groups share findings with the class, discuss variances, and explore the impact of the experiment on lesson objectives. Learning objectives (Common Core/Next Generation): 4.NF.A.2 Extend understanding of fraction equivalence and ordering Compare two fractions with different numerators and different denominators, e.g., by creating common denominators/numerators, or comparing to a benchmark fraction. Record results of comparisons with symbols and justify conclusions, e.g., by using a visual fraction model. 2.MD.1 Measure the length of an object by selecting and using appropriate tools such as rulers. 2.MD.3 Estimate lengths using units of inches. 3.MD.4 Generate measurement data by measuring lengths. MP6: Attend to Precision Mathematically proficient students try to communicate precisely. They try to use clear definitions in discussion and in their own reasoning. They are careful about specifying units of measure, and... express numerical answers with a degree of precision appropriate for the problem context. MP3: Construct viable arguments and critique the reasoning of others Mathematically proficient students... justify conclusions, communicate and respond to arguments... construct arguments using concrete

referents such as objects, drawings, diagrams, actions. Science & Engineering Practices: Developing and Using Models Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system. Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon.

3:15 *Expanding STEM Outreach Through Multi-Generational Reach: Establishing Library Based STEM Programs*

Ralph Tillinghast (US Army & ARDEC, Picatinny Arsenal, NJ, USA); Edward Petersen and George Fischer (US Army, USA); and Mo Mansouri (Stevens Institute of Technology, USA)

STEM outreach continues to grow and be an effective means to inspire young minds. Finding the optimal path and method to reach these students still continues to be a focus for educators and researchers. As with any system, there is a complex network of influencing factors and stakeholders that ensure the system operates effectively. This paper examines methods to utilize stakeholders outside of the typical STEM outreach system. Specifically looking at multi-generational outreach, such as parents, grandparents or extended friends and family, as an additional method to reach students. This is accomplished by reviewing a series of library based programs that are open to pre-K through senior citizens attendees. The paper will present stakeholder considerations for these demographics and a detailed description of the Library based programs being conducted. Lastly a summary of findings related to the library STEM outreach program is presented based on survey assessments conducted during these programs.

3:30 *Design Thinking and Computational Modeling to Stop Illegal Poaching*

Pradyuta Padmanabhan (Foxcroft School, USA); Alexander M Baez and Carmen Caiseda (Inter American University, Puerto Rico - Bayamon, Puerto Rico); Kathleen McClane, Nithin Ellanki and Padmanabhan Seshaiyer (George Mason University, USA); Byong Kwon (Arizona State University, USA); and Erick Alphonce Massawe (Nelson Mandela African Institution of Science and Technology, Tanzania)

In this paper, we describe an interdisciplinary approach using STEM to solving a real-world problem involving poaching. This integrated STEM experience helped a team of researchers that included students from K-12, undergraduate students, graduate students and faculty to collaboratively understand, design and test potential solutions to the problem. The team employed an engineering based Design-Thinking framework combined with effective brainstorming strategies that have been well-established in business, marketing and commercial environments along with a computational mathematics problem solving approach. Not only this integrated STEM experience provided an opportunity for the team of researchers to develop professionally but also gave them an opportunity to become change agents to transform institutional practices and to engage the broader community to inspire the next generation STEM workforce. Specifically, the project framework guided the research team to propose potential integrated STEM based solutions including the application of drones to track illegal poaching as well as the development of an intelligent sensor based tracking system which are validated via sophisticated mathematical and probabilistic algorithms. This overall experience has clearly helped to establish STEM education partnerships and alliances outside traditional boundaries and has helped to create new synergies for all stakeholders who are invested in solving the problem of poaching. Specifically, it has helped to develop an international research experience for high school, undergraduate and graduate students who now have a unique perspective on solving real-world problems in developing countries. The program has helped to promote the much needed awareness of using STEM based solutions to solve global challenges through a multi-disciplinary collaborative approach involving students and faculty from mathematical sciences and engineering who continue to collaborate.

3:45 *Evolution of Digital Literacy Project in Rural India*

Arijit Dutta (Bridgewater Raritan High School, USA)

Students of the iSTEM Club at Bridgewater-Raritan High School started the Digital Literacy project in the village of Paushi, West Bengal back in the summer of 2013. Two phases of the project have since been completed, one in 2013 and one in 2014. The first phase consisted of setting up one desktop system and one printer, which were used to teach the children of the village how to use computers. In phase two, a second desktop system was installed and supplies for the printer were replenished. This paper puts emphasis on the third and final phase of this project, completed in the winter of 2015. In this third phase, a concrete building was built to permanently house the desktop systems and to serve as the new venue for the cyber classroom. In addition, the facilities were further expanded after four additional donated desktop systems were installed in the library.

4:00 *EPICS in IEEE: Encouraging the Pursuit of Engineering for Community Improvement*

Ray Alcantara (IEEE, USA)

Featured presentation on the IEEE EPICS Program.

FC 008 Robotics for K-12 STEM Education

Chair: Ashutosh Dutta (AT&T, USA)

1:30 *Robotics to Promote STEM Learning: Educational Robotics Unit for 4th Grade Science*

Amy Eguchi (Bloomfield College, USA) and Lisbeth Uribe (The School at Columbia, USA)

Educational robotics or Robotics in Education (RiE) is the term widely used to describe the educational use of robotics as a learning tool. Educational robotics is a learning tool to promote students' STEM learning. Educational robotics is rich with opportunities to integrate not only STEM but also many other disciplines, including literacy, social studies, dance, music and art, while giving students the opportunity to find ways to work together to foster collaboration skills, express themselves using the technological tool, problem-solve, and think critically and innovatively. It is a learning tool that enhances students' learning experience through hands-on mind-on learning. Most importantly, educational robotics provides a fun and exciting learning environment because of its hands-on nature and the integration of technology. The paper introduces an educational robotics for 4th grade science, which includes the overview of the unit and the sequence of lessons, and touches upon key instructional strategies. In addition, it explains how the learning standards are addressed in the unit.

1:45 *Hands-on Workshop: Using Robots in K-12 STEAM Education*

Howard Michel (UBTech Education, USA); Jack Wang (UBTech Education, P.R. China)

K-12 teachers, parents and others interested in STEAM education will gain experience in using robots in STEAM education, including assembling a robot, basic robot programming and use of the robots to demonstrate physics principals.The workshop will be conducted as a hand-on interactive session using UBTech uKit and Alpha 1x robots. The workshop will illustrate ways of engaging students in critical and creative thinking based on collaborative exercises with robots. Conducted as a STEAM lesson itself, the workshop is grounded in a learning process of asking questions, facilitating group discussions, exploring possible solutions, constructing robots, evaluating their usefulness in answering the original question or illustrating concepts, and generalizing the robot solution to generate more questions.

3:45 *Project-based, Collaborative, Algorithmic Robotics for High School Students: Programming Self-driving Race Cars at MIT*

Sertac Karaman (MIT, USA); Ariel Anders (MIT & CSAIL, USA); Michael Boulet (MIT Lincoln Laboratory, USA); Jane Connor (Massachusetts Institute of Technology, USA); Kenneth Gregson (MIT Lincoln Laboratory, USA); Winter J Guerra (MIT, USA); Owen Guldner (MIT Lincoln Laboratory, USA); Mubarik Mohamoud and Brian Plancher (MIT, USA); Robert Shin and John Vivilecchia (MIT Lincoln Laboratory, USA)

We describe the pedagogy behind the MIT Beaver Works Summer Institute Robotics Program, a new high-school STEM program in robotics. The program utilizes state-of-the-art sensors and embedded computers for mobile robotics. These components are carried on an exciting 1/10-scale race-car platform. The program has three salient, distinguishing features: (i) it focuses on robotics software systems: the students design and build robotics software towards real-world applications, without being distracted by hardware issues; (ii) it champions project-based learning: the students learn through weekly project assignments and a final course challenge; (iii) the learning is implemented in a collaborative fashion: the students learn the basics of collaboration and technical communication in lectures, and they work in teams to design and implement their software systems. The program was offered as a four-week residential program at MIT in the summer of 2016. In this paper, we provide the details of this new program, its teaching objectives, and its results. We also briefly discuss future directions and opportunities.

4:00 *Robotics: An Interdisciplinary Approach To STEM*

Howard Kimmel, Ronald Rockland, Levelle Burr-Alexander, John Carpinelli, and Linda S. Hirsch (New Jersey Institute of Technology, USA)

Because of its multidisciplinary nature, the use of robotics in the classroom is a valuable tool for the practical, hands-on application of concepts across various mathematics, pre-engineering, and science topics. A pre-engineering program called Medibotics, was developed to introduce teachers and their students to bio-medical applications of robotics using LEGO Mindstorms Robotics kits for Schools and NXT software. The multiple fields of science, such as biology and medicine, and engineering, from electrical engineering to mechanical engineering were combined with information technology (computer programming) to form a teaching tool that enabled students to recognize direct links between their science courses and engineering in the real world. The curriculum materials incorporated grade-appropriate prototypes of robotic surgeries into middle and high school pre-engineering and science curricula that provided students with hands-on experiences that simulated real-world problems. Teachers were trained on how to incorporate the Medibotics curriculum materials into their classroom teaching during an intensive professional development program.

FC Foyer and Convocation Room

Chair: Wei-hsing Wang (Princeton International School of Mathematics and Science, USA)

Predicting Math Test Scores Using K-Nearest Neighbor

Jessica Brown (Clarksburg High School, USA)

It is hard to predict student test scores in Mathematics. By being able to predict test scores students that will struggle may be identified. They could be given more attention. This research uses the K-Nearest Neighbor (KNN) algorithm to predict the categorization of Mathematics test scores. The KNN algorithm initiates with training data set and a value for parameter K. When evaluating a test record it compares the Euclidean distance between the test record and each of the training records. It examines the K training records closest to the test record. KNN's predicted category is the most common category of these K records. The data used in this research comes from a dataset of 395 records of Portuguese students. Each student record contained 30 data elements about the student including gender, age, travel time to school, if they were dating and the number of days they were absent. Portuguese students are given 3 Mathematics tests that have a score ranging from 0 to 20. To categorize students this research averaged the 3 test scores and created 4 categories. Students scoring 0 to 5, 5 to 10, 10 to 15 and 15 to 20 were categorized as low, slightly below average, slightly above average and high respectively. Half of the records in the dataset were used as training records. The other half was used as test records. Values of K equal to 1 through 20 were evaluated. KNN did very well; it predicted the category correctly 48.78% of the time. The best value was when K = 8. The worst value was K = 1. This research can be helpful in identifying students that might need assistance. It can also be used in identifying students for advance classes and students to be mentors.

Utilizing a Network of Wireless Weather Stations to Forecast Weather in Developing Countries

Turner M. Bumbary (Thomas Jefferson High School for Science and Technology, USA)

Each year extreme weather causes nearly 100,000 mortalities, with most of these deaths being concentrated in third world and developing countries. Additionally extreme weather events account for $485 billion in US economic damage, with this number expected to inflate as global warming increases the frequency and intensity of natural disasters. However, the effects can be even more devastating in poor communities, as they have neither the financial capital, nor the infrastructure to support a network of permanent weather stations. As a result, agriculturalists and debilitated citizens are not able to prepare for damaging long-term weather events, which inevitably causes crop failure, famine, and increases the risk of mortalities. The purpose of this research is to develop an inexpensive infrastructure of weather stations, to create more accurate forecasting networks for citizens and governmental officials of third world and developing countries. This research will compare the precession of inexpensive weather stations to commercial grade weather nodes, and data gathered from the National Oceanic and Atmospheric Administration. Finally, the research will assess the forecasting accuracy of the inexpensive forecasting technology systems, against popular weather media such as The Weather Channel© and the National Weather Service . The ultimate goal of this developmental project is to install the inexpensive weather infrastructure in developing countries, in order to help government officials accurately forecast and prepare for critical weather events.

Reconstruction of Ancestral Tumor Necrosis Factor-Alpha

Yinuo Han (Princeton International School of Mathematics and Science, USA) and Ruoqian Xiong (Duke University, USA)

Ancestral protein reconstruction aims to resurrect ancestral proteins from now-extinct species to directly measure protein functions in vitro. Mapping amino acid sequences onto a phylogenetic tree, in addition to measurements of protein functions, can potentially reveal rich information about protein evolution. This study focuses on tumor necrosis factor-alpha (TNF-α), a pleiotropic pro-inflammatory cytokine. Abundant evidence suggests that TNF-α plays a key role in inducing several immune-mediated diseases that involve chronic inflammation; however, more knowledge about this protein is required in order to explain the pathogenesis of these diseases. Using gene sequences from 19 extant primate species (and an outgroup), we reconstructed TNF-α sequences for 19 ancestral nodes ranging in estimated age from 10-60 million years before present and including the common ancestor of all primates. Ancestral sequences were inferred using Phylogenetic Analysis by Maximum Likelihood (PAML v4.0). In terms of the number of amino acid changes in TNF-α, we found out 1) overall, most putative changes in TNF-a occurred in terminal taxa, with significantly less evolution change occurring at ancestral nodes; 2) very little evolution of TNF-α happened during the first two bifurcations in primate history; 3) the amount of evolutionary change among all primates was largest (12-21 putative changes) at terminal branches in the Ceboidea and Strepsirrhini; 4) within the Cercopithecoidea and the Hominoidea, few amino acid changes (0-2) occurred at most ancestral nodes, whereas between 5 to 12 changes occurred on each terminal branch (extant species). Ongoing work includes expression of ancestral TNF-α proteins using a cell-free transcription-translation system (TX-TL) and functional

assays for testing functional differences between select ancestral and extant TNF-α proteins. Results from this research study will offer insights into the evolution of the structure-function relationship of TNF-a and could expand our knowledge about cytokine activities in the complex immune system.

In silico Evaluation of a Hydrogen Production System with Enzyme Produced from Cell-Free Protein Synthesis

Jiaqi Huang (Princeton International School of Mathematics and Science, USA)

Producing hydrogen from carbohydrates economically requires an efficient and long-enduring catalytic reformer. Due to the properties of enzymes, synthetic enzymatic reformers have the advantage in reaction rate over non-enzymatic catalytic reformers, but short endurance is the main problem of traditional enzymatic reformers. I propose a solution to the endurance problem of enzymatic reformers by introducing new components to divert some of the energy produced by the enzymatic pathway to produce new enzymes for the synthetic pathway. A cell-free TX-TL system produces the enzyme in the hydrogen producing pathway from energy diverted from the pathway by oxidative phosphorylation in inverted membrane vesicles. I use a combination of ordinary differential equations and flux balanced analysis to model the system, with a genetic algorithm to optimize the initial enzyme and DNA loading. According to the optimized computer model, this integrated system increases the production rate of hydrogen beyond 100 hours by more than two orders of magnitude, or about 300 fold. Although it still needs further validation and improvements, there are a number of potential applications of this system, including protein production and electricity production.

Multimodal Detecting & Analytic System for Visual Perception and Emotional Response

Kunpeng Huang (Princeton International School of Mathematics and Science, USA)

The correlation between visual perception and the evoked emotional response has been investigated extensively in the area of cognitive psychology using the method of electroencephalography(EEG). While EEG could record the cerebral activities accurately, the subject's visual attention was always left out of consideration. In the study, we proposed and developed a multimodal detecting and analytic system for visual perception and emotional response using a combination of EEG, eye tracking and heart rate. The effectiveness of the system was tested by an experiment based on negative, positive and neutral images selected from ThuPIS image system. 10 participants took part in the experiment and their emotions were analyzed in valence and arousal dimensions as they were observing the images. The results indicated positive correlations between valence and power of electroencephalography signals over the occipital lobe at low frequencies and over the left and right temporal lobes at high frequencies. The saccade magnitude and fixation duration of eye movements could also function as indicators of emotion. We designed a compact module of the system for psychological diagnosis and treatment. Our system may contribute to improve the precision of visual-based psychological treatment by providing real-time emotion analysis.

Surface Modified Porous Silicon as Bacterial Trap

Paulina Kulyavtsev (Princeton International School of Mathematics and Science, USA)

Porous silicon (pSi) is a mesoporous semiconductor with high surface area, and customizable pore morphology that historically was used for optical sensing. pSi is biocompatible, readily forming orthosilicic acid ($Si(OH)_4$) in vivo with no adverse side-effects, and its use for subcutaneous drug delivery is being explored. The ongoing work is directed to a proof of concept design of a bacterial filter based on surface modification of p-type pSi. pSi was prepared by stain etching of Si-100 wafers using potassium permanganate and sodium nitrite in sulfuric acid/hydrofluoric acid. Post-etching, surface silicon-hydride bonds were observed by attenuated total reflection (ATR) infrared spectroscopy, pores were observable by atomic force microscopy, and visible photoluminescence was observed when illuminated at 254 nm. Biphenylamino molecules synthesized by Suzuki coupling of arylboronic acid and variably substituted anilines will be attached to the pSi surface using aryldiazonium salts. In future, a small molecule that could mimic the function of mannose binding lectin for toxin and pathogen removal from blood will be designed. This process aims to create a robust low cost, efficient, and easily replicable product made from readily available materials. As such, it may be possible to design a biomedical device to clean blood or deliver drugs with minimum invasion and side effects.

Making and Knowing - Metal Casting

Yingyi (Olina) Liang (Princeton International School of Mathematics and Science, USA)

BnF Ms. Fr. 640, a 16th century manuscript that includes detailed instructions for many processes ranging from tree planting to dye making, is being translated and annotated by historians in The Making and Knowing Project. Many pages are devoted to metal casting, and my research focuses on physical and chemical changes in casting. Casting in the 16th century used combinations of different metals, molding materials, and binders to reproduce designs; I investigated the effect of different binders—the liquids used to increase its plasticity and strength of the mold—on casts of tin and lead.

Many materials can be used for the mold, including ox bone, oyster shells, coal, and even sugar. In this work, white quartz sand was used with four different binders: water for a benchmark, egg white, elm root boiled with vinegar, and elm root boiled with wine. All molds were used when the sand would "give a nice hold" while still coming apart easily according to a "squeeze test" mentioned in BnF Ms. Fr. 640. The squared bottle bottom with regular details was depressed into the sand-binder mixture to create a mold about 3cm by 3cm, 0.5cm deep. Molten metal was poured into the cavity left by the bottle in the sand, and after cooling, emblems were visually and microscopically inspected. Molds made by water only produced a general square shape, while molds with other binders gave finer details. The squeeze test was helpful to determine an appropriate ratio of sand to binder. Ongoing analysis of the surfaces and cross section of the emblems by scanning electron microscopy is being pursed to understand any structural differences.

Design and Implementation of a Distraction-Based Polygraph

Shuangzhe Lin (Princeton International School of Mathematics and Science, USA)

Researchers are trying to improve the accuracy of polygraphs used in lie detection process. Many methods have been incorporated into different types of devices which exist on market. A distraction- based polygraph is an innovative project that intents to interrupt participants' attention on making up lies, which could help them pass through deception test, by a gaming system that distracts participants throughout the lie detection process when they are answering questions asked by examiners. Now this project is in progress, designed and implemented by a high school student for research and development course provided by his school. The gaming system simulates the popular and easy- learnt video game, Flappy Bird. Physiological data are measured by different devices assembled into a larger portable machinery. All the data and graphical programs work on a programming platform, called Processing. This project may shed lights on future lie detection methods and process.

Testing the Susceptibility of Pseudomonas and Staphylococcus to Manuka Honey

Ibnat Meah (Dallatown Area Middle School, USA)

Due to bacteria's ability to build resistance to antibiotics, many antibiotics do not stay effective for long. New ways to treat diseases caused by bacteria are sought, manuka honey being one available option. Bacteria have a harder time building resistance to manuka honey because of its various mechanisms that kill bacteria on different levels. This experiment will be testing the susceptibility of Pseudomonas aeruginosa and Staphylococcus aureus to various manuka honey concentrations, a series of antibiotics, and a household cleaner. To do so, the Kirby-Bauer method and a serial dilution were conducted. The Kirby-Bauer method deemed the manuka honey effective at higher concentrations as noticeable zones of inhibitions were present. All the antibiotics were effective on the Staphylococcus, while penicillin and ampicillin had no effect on the Pseudomonas. The serial dilution results showed that the manuka honey was modestly effective at higher concentrations, the clorox bleach spray was also effective at higher concentrations. Overall, the manuka honey was successful at killing bacteria at higher concentrations.

Inspiring Student Advocacy of STEM in the Community

Amr Metwally (ILITE Robotics, USA)

The student leadership team of ILITE Robotics Team 1885, whose acronym stands for "Inspiring leaders in Technology and Engineering", would like to present a poster detailing ILITE's execution of its mission to inspire student advocacy of STEM in the community at ISEC 2017. Well known and established in the community, ILITE hopes to convey this year's theme of connecting the dots in an easily understood presentation capable of being seamlessly integrated into any curriculum. ILITE has pursued STEM equity passionately in its 12-year history and serves as the foundation for STEM in the community. To better engage in our mission of inspiring young people to become leaders in STEM, ILITE has a multitude of outreach activities. Whether it be through our summer camps that teach hundreds of students about STEM, or our annually-hosted FIRST competitions, ILITE continuously inspires those around them. ILITE believes that the next generation of innovators, problem solvers, and game changers are present in those around us. But first, they must embrace STEM to build the skills that will serve as their tool set for the future. For that to happen, we must work together to ignite their curiosity and get them excited about STEM in their everyday lives.

Novel Device to Detect Extreme Temperatures and Prevent Injuries in Patients Suffering From Peripheral Neuropathy

Vishnu Murthy and Aaraj Vij (Thomas Jefferson High School for Science and Technology, USA)

The TeCNail is an artificial nail worn on the index-finger nail that alerts the user to objects and surroundings with extreme temperatures thus preventing burns or frostbite to the users fingers. Over 42 million people around the world suffer from peripheral neuropathy, which is the deterioration of nerves in the peripheral nervous system. Peripheral neuropathy is caused by autoimmune diseases, diabetes, chemotherapy, alcoholism, exposure to toxins, infections and more. Current

solutions on the market either provide symptomatic relief for damaged nerves in patients with peripheral neuropathy but are not preventative or are preventative but extremely intrusive. Our solution to this problem is TeCNail which houses a miniature infrared sensor, processing chip, LED, speaker and lithium battery.The infrared sensor detects temperatures outside the range of 0°C to 44°C from a distance of ten inches, activates the LED to blink and the speaker to beep to immediately caution the user from touching the object. The body of the nail has a curved shape which allows for easy conformity to a users fingernail. The infrared sensors function is to detect the temperature of the environment surrounding the users fingers and relay this information to the processing chip. The sensor is located on the edge of the TeCNail and can sense temperatures 2-3 inches away with a 0.5°C variance. The processing chip which is located in the center of the TeCNail, reads the electric signals from the detector, and depending on the temperature can send electrical signals to the LED and speaker. The integration of the above components will create a streamlined interface, powered by a series of chain reactions in order to alert the user if their finger is exposed to an unsafe temperature.

Targeted Genetic Mutation to OmpA in E. coli and the Effect on its Susceptibility to the K3 Virus

Yutian Ou (Princeton International School of Mathematics and Science, USA)

The outer membrane protein A (OmpA) in E. coli serves many function, including selective binding to sugars and small molecules, as well as serving as a phage receptor. OmpA has two domains, with the N-terminal domain (170 aa) made up of an antiparallel -barrel transmembrane region that forms four hydrophilic, surfaced-exposed loops. Extra-membranous loops often serve important functions in proteins. Earlier studies in the structure and function of OmpA explored the effects of deleting one or more of these transmembrane loops, particularly with regards to their interaction with several bacteriophages. One study demonstrated that the removal of loops 1, 2, or 3 was sufficient to prevent infection by the K3 virus, presumably because the virus interacts with the loops for entry. Another study demonstrated that naturally occurring mutations in loop two was sufficient to make E. coli resistant to K3 (naturally occurring mutations in the remaining loops had not effect). The aim of this study is to make specific, targeted mutations of single amino acids in loops one, two, and three in order to identify the specific amino acids in each loop that interact with the K3 virus. Mutations are induced using the FRUIT method (Flexible Recombineering Utilizing Integration of thyA).

Design and Implementation of a Distance-based, Three-dimensional Vision System

Fei Peng (Princeton International School of Mathematics and Science, USA)

One technical challenge in the field of computer vision is to precisely and robustly acquire information in three dimensions from an arbitrary, dynamic environment. There have been successful algorithms that focus on the precision and robustness, the three-dimension aspect, or the generality of the vision system, yet none of them performs very well in all these aspects and approach the level of human vision. The research problem of this project is to design and implement a distance-based, three-dimensional vision system, that meanwhile is robust in a variety of arbitrary, dynamic environments. A set of a red-green-blue camera and a distance measurer is adopted for the measurement of the surrounding. The data acquired are planned to be interpreted by the computer algorithm and form a three-dimensional model. To build the prototype, multiple equipments in the school lab were utilized. A RaspberryPi camera module and an HC-SR04 ultrasonic sensor were adopted respectively as the red-green-blue camera and the distance measurer. A laser cutter was used to shape the main body of the robot. Other parts include three omnidirectional wheels, four servos, and a RaspberryPi B+ shield. An instruction to duplicate this project is included in the Project Brief section. Several qualitative and quantitative objectives were listed at the start of the project, and were assessed later by analyzing the frequency and accuracy of the parts. We look forward to a completed implementation of the project, so that it could be applied to future landscaping, human recognition, or robot soccer.

The Design and Implementation of a Novel Motor System for a Microcompressor

Justin Saintil (Princeton International School of Mathematics and Science, USA)

This project revolves around the implementation of a motor system to a microcompressor allowing for precise control and manipulation of the compressor. This research will test the effectiveness of said system in inhibiting the movement of organisms when imaging. A microcompressor is a device that uses two cover slips to physically inhibit the movement of specimen. This project serves to fix a common issue that occurs when imaging microorganisms. It is imperative when imaging motile specimens, that they are immobilized in some way to avoid movement and migration. When imaging from a three-dimensional perspective, you must have some sort of force to counteract the Brownian motion attributed to the media the specimen is in or cell dynamics that are powered by cilia and flagella. Not only is there need for a proper system that would serve to immobilize cells, but there would also have to be a very precise control mechanism to ensure that the cell is not being crushed or improperly manipulated. This mechanism would also have to be compatible with microscopes to provide effective immobilization while imaging cells. This project further develops a novel device created by Dr. Janetopoulos at the University of Sciences, as he has created a microcompressor that, using brass rings and cover slips,

physically inhibits the movement of specimen. I will be creating a motor mount system to add onto this compressor. In order to conduct my project I not only have to understand the structure of the compressor but motor dynamics and the tools I will need to complete the project.

An Empirical Study of STEM and Chess Relevance

Kyle Sheu (Whitney High School, USA)

Motivation - As an advocate for chess and other brain teaser games, I am interested in discovering whether such fun activities can help students become interested in and feel more confident about STEM subjects. I often hear my classmates say that smart kids play chess rather than that chess makes kids smart, and I would like to verify the validity of this through an empirical study. I want to leverage my statistical reasoning skills and my programming skills to discover relevance in this intertwined arena. Survey Summary - The anonymous survey was conducted via Google Forms to one high school, one CSU campus, and one UC campus. 177 eligible responses were collected, with 57 from the high school and the rest from the two college campuses. Data Analysis Method - I analyzed correlation between when one started playing, time at which one felt confident in math, and other relevant data across ethnic groups; analyzed influence of parent education or other factors on when one started playing, whether he/she liked math, and when he/she felt confident about math; and calculated significance level and other statistical outcomes. The analysis was performed in R programming and is visualized using graphical tool packages imported to R Studio. Visualization is enhanced by displaying multiple factors in a two dimension coordinate system leveraging various visual indicators. Multidimensional exhibitions provide some insight into an intertwined arena that may have puzzled educators. Findings - With some variation across ethnic groups, the impact of playing chess on STEM education is substantial. In general, liking math strongly correlates to liking other STEM subjects. Some correlation exists between when one started playing chess and when one starts feeling confident in math. Overall, the study suggests that it is of benefit to STEM education to play more chess and to play earlier.

Common Core: Challenges and Opportunities to Incorporate Nonfiction into K-12 Curriculum

Adway Wadekar (Sarah W. Gibbons Middle School, USA) and Swapna S. Gokhale (University of Connecticut, USA)

The Common Core standards recommend an integration of nonfiction literature into the K-12 curriculum. Anecdotal evidence, however, indicates that students are not receptive to reading nonfiction or informational material. Therefore, the first objective of this project is to examine the extent to which K-12 students, divided across gender, grade level, and school type prefer reading fiction over nonfiction literature. The project then takes a step further in investigating whether students show an overwhelming (dis)like for specific fiction and nonfiction subgenres. Using a survey-based approach to answer these questions, the project discovered the following trends: (i) male and lower elementary students prefer nonfiction compared to female, middle school, and high school students; (ii) nonfiction subgenres can be clustered into groups based on students' interests, and (iii) very weak penchant is seen for physical sciences. Taken together, these trends identify challenges and opportunities to integrate nonfiction materials into the K-12 curriculum.

Notes

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Save the Date!

8th IEEE Integrated STEM Education Conference

Saturday, March 10, 2018

Friend Center at Princeton University