2019 Symposium on Education in Entertainment and Engineering

SYMPOSIUM PROGRAM

JULY 25 AND 26, 2019
WEST LAFAYETTE, INDIANA

PURDUE UNIVERSITY

Multidisciplinary Engineering
SCHOOL OF ENGINEERING EDUCATION

Department of Theatre
COLLEGE OF LIBERAL ARTS

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Welcome to the Inaugural Symposium on Education in Entertainment and Engineering!

Do I contradict myself? Very well then I contradict myself, (I am large, I contain multitudes.) These lines, from Walt Whitman's *Song of Myself*, have echoed in my head throughout my career. Our world sometimes wants to define each of us within narrow categories ("engineer," "theatre technician," "educator"); just recently, I was encouraged in a professional mentoring meeting to start thinking about choosing which of my interests in stortytelling, technology on stage, technical design, or instructional design I would start focusing on as my specialization. That's an impossible choice in my mind: each of these areas of research and interest inform and are enriched by the others, and my practice would be lessened by making such a choice.

I am fortunate to have a like-minded partner and colleague in Mary Pilotte, with whom I've been able to craft an educational journey for students that is intentionally silo-breaking, embracing the multitudes our students contain. In the past five years, I've been blessed to meet students who love stories and machines; who are passionate about amusement parks and the fantastic worlds they allow us to explore; who are fascinated with control systems and the animatronic characters they bring to life. Their interests combine multiple domains, and challenge us to find ways to make those combinations possible.

My hope for this Symposium is that it provides opportunities to build connections among other like-minded mold-breakers, whose journeys and passions have taken—and continue to take—them across traditional disciplinary boundaries. Thanks to all of you for sharing your time, your energy, and your passions with us.

Rich Dionne

Adventurous interdisciplinarity and collaborative/engaging pedagogies of instruction are values that reside at the heart of the domain of Engineering Education (ENE). So nearly 5 years ago, when I became Director of ENE's undergraduate programs for interdisciplinary engineering studies and multidisciplinary engineering and was introduced to like-minded soul Professor Rich Dionne from the Theatre department, it was like "coming home" to a warm familiar place. Little did we know that our first meeting would be laying the groundwork for the grand collaboration we are sharing in today.

At the time we met, we had a few undergraduate engineering students "dabbling" in the arts, their pathways each hand carved, and one of a kind. Fast forward to today, where we now have two established Theatre Engineering plans of study, we have nearly 20 students either in the pipeline or graduated from these plans, we have co-hosted our first USITT Regional Machine Design Competition, and now stand before you in a formal symposium, one that was born out of a "crazy idea" one day in Chicago.

While each time compressed and residing in our respective disciplinary silos, time spent on these collaborative efforts have multiplied opportunities for our respective programs and students many times over, beside paying personal dividends from joyful collaboration. Our work together has not only been a pleasure, it has resonated for many students who until now, probably made difficult career choices; the kind that swap stability for passion, and challenge the idea that you can actually be all engineer, and all in for the arts as well.

For all that we have accomplished together, we are just getting started. There are so many more "crazy ideas" we hope to bring to life. We most sincerely thank you for sharing your talents and being willing to join in our creative sandbox. We also hope you will be inspired by the many talents and perspectives that are shared today—in the same way our mutual students have inspired both Rich and myself.

Mary Pilotte

Symposium Co-Hosts

Rich Dionne
Purdue University

Rich Dionne is an Associate Professor of Practice and technical director in the Department of Theatre in the Patti and Rusty Rueff School of Design, Art, and Performance at Purdue University. He specializes in scenery automation and show control systems while also serving as the department's production manager. He has a passion for both the art of theatre and the science and engineering of making theatre happen. Rich is a founding Faculty Fellow of the Purdue Polytechnic Institute, and has served as the technical director for numerous productions in the Department of Theatre. He teaches courses in structural and mechanical design for the stage, automation controls and show networks, project planning and advanced arena rigging to students in theatre and theatre engineering.

Prior to coming to Purdue, Rich was the production manager and resident sound designer at The Shakespeare Theatre of New Jersey, where he mounted numerous productions at various indoor and outdoor venues, including a nationally-recognized educational touring company. Additionally, he has served as the technical director for Berkshire Theatre Festival, Alpine Theatre Project, Weston Playhouse Theatre Company, and Dorset Theatre Festival, mounting critically-acclaimed productions including *The Whipping Man*, *Barefoot in the Park*, *Amadeus*, *Night of the Iguana*, *Avenue Q*, *The Illusion*, and *Death of a Salesman*. Rich's book, *Project Planning for the Stage: Tools and Techniques for Managing Extraordinary Performances*, focused on the application of project planning techniques for theatrical production, was recently published by Southern Illinois University Press. The eighth edition of *Theatrical Design and Production*, for which he is a co-author with Michael Gillette, was recently published by McGraw-Hill.

Mary K. Pilotte
Purdue University

Dr. Mary Pilotte is an Associate Professor of Engineering Practice and is also Director of the School of Engineering Education's Undergraduate degree programs in Interdisciplinary Engineering Studies and Multidisciplinary Engineering.

She teaches varied topics across levels of student development, from professional development to engineering economics and Senior Capstone Design. Outside of the College of Engineering she instructs project management and consulting approaches for the Global and Executive MBA programs at the Krannert School of Management at Purdue, and heads corporate workshops based on her book *Millennial Reset* (2018) and on Intentional Learning.

Her research interests include engineering work culture including generations-based engineering practices and norms, examining what it means to identify as "multidisciplinary", and exploring new approaches and dynamic strategies around increasing workplace diversity, especially for the neurodiverse, and those with invisible differences.

Prior to her roles in the academic setting, she worked professionally for more than 20 years in the automotive, aerospace, airline, and commercial products industries, holding a variety of titles. She lead high performing teams in manufacturing, design-engineering for new product and process development, and ultimately in plant management and finance completing strategic mergers and acquisitions.

Symposium Schedule

Thursday, July 25, 2019		
6:30 PM	**Early Registration Opens**	**Armstrong Atrium**
7:00 PM	**Welcome Reception and Plenary Remarks with Dionne/ Pilotte**	**Armstrong Atrium**

Friday, July 26, 2019		
7:30 AM	**Registration Opens**	**Stewart Center, Room 214A**
8:30 AM	**Performance as Pedagogy** *Understanding the Nuremberg Trials: An Examination of the Use of Live Theatre as an Educational Tool*, Amanda Mayes *Exploring Diversity Issues Through Robot Theater*, Denise Szecsei	**Stewart Center, Room 214D**
9:45 AM	**Morning Panel Session** **Engineering and Entertainment: An Academic Perspective** Mary Pilotte (moderator), Mark Budnik, Dan Lisowski, Ann Shanahan, Donna Riley	**Stewart Center, Room 214B/C**
11:00 AM	**Beauty in Engineering and the Performing Arts** *Beauty in Engineering and the Performing Arts*, Robert Klimek, Catherine Skokan, John Persichetti, Jonathan Cullison	**Stewart Center, Room 214D**
12:00 PM	**Lunch**	**Stewart Center, Room 214A**
1:00 PM	**Robot Theatre Performance**	**Mallett Theatre, Pao Hall**
2:00 PM	**Afternoon Panel Session** **Engineering and Entertainment: An Industry Perspective** Rich Dionne (moderator), Alvah Aldrich, Amanda Grimm, Beth Martell	**Stewart Center, Room 214B/C**
3:15 PM	**Experiential Learning and Tool Building** *International Competition as Stopgap Curriculum*, Kathryn Woodcock *Acoustic Engineering Workstation*, Geoffrey Akers, Nic White	**Stewart Center, Room 214D**
4:30 PM	**Engineering Art** *Undergraduate Capstone Project: A Graphic Rain System*, Katherine Metzler *Photonics for Historical and Modern Visual Arts*, Alexandra Boltasseva, Sarah N. Chowdhury, Piotr Nyga	**Stewart Center, Room 214D**
6:00 PM	**Dinner and Plenary Remarks with Dionne/Pilotte**	**West Gallery, Pao Hall**

Presentation Abstracts

in alphabetical order by the lead presenter's last name

Acoustic Engineering Workstation

Geoffrey Akers, Nic White, College of the Ozarks

The College of the Ozarks is developing the ability to offer acoustic engineering services to on and off-campus customers. The College is the only federally-recognized work college with an engineering program. Students do not pay tuition and are assigned work stations on campus to help defray expenses and to generate income for the College. The engineering program began in 2016, and the Engineering Services workstation began in 2018 with one engineering student supervised by an engineering faculty member. The workstation has two primary objectives. The first is to provide a learning environment for engineering student workers, which includes field experience in the engineering design process, project management, customer interaction, and mentorship by faculty, industry partners, and local engineers. The second is to provide services to campus and off-campus customers. This paper addresses the purpose and administration of the workstation, the perceived benefit to the student workers and the engineering program, as well as the recent work station accomplishments. At a minimum, the accomplishments will include designing, fabricating, testing, and analyzing acoustic panels for a small sound studio, as well as measurements of the small studio before and after the acoustic treatments.

3:15 pm, Stewart Center, Room 214D

Photonics for Historical and Modern Visual Arts

Alexandra Boltasseva, Sarah N. Chowdhury, Piotr Nyga, Purdue University

The impact of photonic technologies on our society cannot be overestimated; by controlling light, photonics is finding a home in art and design. Microscopy, spectroscopy, hyperspectral imaging and interferometry are tools for unlocking details in centuries-old paintings and enable old paintings and frescos to be preserved. A recent study has investigated how optics was used to create art centuries ago, unlocking the secrets of renowned artists, such as Bellini and Caravaggio, who appear to have used optical projections to guide the proportions in the scene. Lasers have been work horses on performance stages and in museums allowing artists to do new things by enabling fascinating animation, graphics and magical, "alive" museum portraits.

Recent developments in ultra-thin, flat optics enabled by metamaterials and metasurfaces has expanded the realm of lenses and holograms include extremely thin meta-coatings instead of bulky, volumetric components. These new metasurfaces bring significant advancements into hologram technology with potential impact on visual arts via ultra-compact, easy-to-make, robust and full-colored holograms. New concepts for light manipulation with metamaterials, metasurfaces and photonic crystals could further enhance artists' capabilities.

This cross-disciplinary talk will give an overview of optical approaches for historical and visual arts involving a wide range of optical designs and materials that merge engineering and arts, such as ceramics, colored glasses (such as those hosted by the Corning Museum of Glass), optical fibers for entertainment and fashion textiles, and more.

4:30 pm, Stewart Center, Room 214D

Understanding the Nuremberg Trials: An Examination of the Use of Live Theatre as an Educational Tool

Amanda Mayes, Purdue University

Does experiencing a live theatrical performance help college students contextualize academic content? What benefits do students gain from the performance outside of the stereotypical textbook readings and class discussions? Survey research conducted at Purdue University indicates exposure to live performances offers significant benefits for college students in their ability to understand and critically analyze the historical events they learn within their coursework. Our research indicates that live theatre could assist in enhancing traditional education models at the collegiate level and should be explored further as a potential methodology to aid in student success.

8:30 am, Stewart Center, Room 214D

Undergraduate Capstone Project: A Graphic Rain System

Katherine Metzler, SUNY Buffalo

A graphic rain system displays visual shapes in the patterns of rain droplets as they fall. Any such system must be closed loop, recycling water with little loss over time and incorporate a self-contained reservoir. Ideally, such a system must be able to display multiple, recognizable shapes as the water droplets fall, and be operated by a user with minimal training. And, of course, all elements of the system must adhere to relevant and appropriate safety codes.

Mechanical engineering students at University at Buffalo-SUNY enroll in a capstone design course in their senior year. Typically, students in this course form small groups and are assigned a challenge by the instructor; during the course of the semester, students progress through a design process to generate a prototype solution to the challenge they've been given. In some instances, students can bring a specific design challenge that matches their career goals and passions, and are permitted to design a solution to that challenge instead.

As part of her capstone project, Metzler undertook to create a small scale version of a graphic rain system. During this presentation, Metzler will share the details of the specific design challenge as well as the solution she has pursued in achieving the design goal. Additionally, Metzler will discuss how this capstone project has allowed her to merge her twin passions of art and engineering. Further, she will examine how this project has provided her with an opportunity to explore both artistic expression and deeper understanding of technological and engineering principles.

4:30 pm, Stewart Center, Room 214D

Beauty in Engineering and the Performing Arts

Catherine Skokan, Jonathan Cullison, John Persichetti, Robert Klimek, Colorado School of Mines

This panel presentation will be led by two engineering faculty and two Music and the Performing Arts professors, all of whom work closely in collaboration at Colorado School of Mines (CSM). The presentation will be a combination of discussion, demonstration and 'hands on' challenges.

The engineering design process has been represented in many ways but can generally be distilled into an iteration of elements that include design, construction, evaluation, and cycling back through redesign until a polished final product is achieved. Music composition and performance use this same process. Likewise, any theatrical production follows a similar envisioned approach that, with the keen eye of a director, is subject to iterative manipulation of staging, blocking and lighting/sound effects, all to fit within the constraints of a particular stage, abilities of those involved, and budget. And, we cannot disregard the same step-by-step process in the visual arts.

History has shown us that many masters of creative genius were both "engineer" and "artist"—those who gave us the engineering marvels of the Egyptian Pyramids, the beauty of Michael Angelo's Sistine Chapel, DaVinci's paintings and the many designers of musical instruments and performance spaces. Why is it then that these creative endeavors are often seen as being at opposite ends of the educational spectrum? Also, should engineers be taught to see themselves as "artists?"

11:00 am, Stewart Center, Room 214D

Exploring Diversity Issues Through Robot Theater

Denise Szecsei, University of Iowa

The University of Iowa's Robot Theater Project promotes STEM education and outreach activities primarily using two commercially available robots: NAO humanoid robots, available through SoftBank Robotics, and Cozmo, developed by Anki. Students involved in this project write scripts and program robots to perform theatrical skits on stage in front of live audiences.

In this paper we introduce our Robot Theater Project, describe the framework used to coordinate the behavior of multiple robots in a scene, discuss the challenges with live performances involving robot actors, present the difficulties in using robots from different manufacturers, and share results from our most recent initiative: working with students to develop a series of short skits that focus on exploring human experiences and behavior using robots as actors, where the content of these performances centers on material related to diversity and representation.

8:30 am, Stewart Center, Room 214D

Teaching Rhetoric to Engineers with Shakespeare

John C. Tompkins, Purdue University

This paper presents the use of Shakespeare in the syllabus of a large-format communications class designed for civil engineers. It gives an overview of the course, including the philosophy behind its creation and the particulars of its population. Shakespeare's presence in the course is justified on two grounds: first, that rudimentary acting practice significantly reduces self-consciousness in public speakers and second, that Shakespeare's speeches exemplify classical rhetoric, and are thus grounds for both the practice of persuasion and the study of its parts. The American Shakespeare Centre has used a similar pedagogy to launch its Leadership Programming initiative, which offers communication training to executives and officials through the medium of great speeches from the plays. A sample assignment, rubrics, and a syllabus are provided.

8:30 am, Stewart Center, Room 214D

International competition as stopgap curriculum

Kathryn Woodcock, Ryerson University

Students aspiring to careers in the themed entertainment and attractions industry have few formal options to learn and demonstrate skills and knowledge specific to the industry. Students have shown initiative in developing extracurricular activities, and industry has reached out to offer "next generation" programs and internships. It still remains problematic for industry employers to select the best qualified students from a large pool of aspirants and for motivated candidates to stand out as highly qualified for these opportunities. The Ryerson Invitational Thrill Design Competition (RITDC) was developed to address this problem. RITDC provides learning experiences and performance evaluation with not only completion as an indicator of accomplishment, but concurrent interactive evaluation by judges from industry. As such, although the competition is formally an extracurricular activity, it functions as stopgap curriculum.

RITDC has grown exponentially with the support of industry sponsors. Through participation growth and scope expansion, the competition maintained a focus on specific entry-level professional skills in a unique industry by adopting an interdisciplinary structure. Realistic, focused challenges showcase real skill expectations for entry level professionals and interns, not just technical skills and knowledge but also interdisciplinary collaboration, time management, creative agility, and presentation. Judges from Universal Creative and its partner companies take an avid interest in how teams adjust to time pressures, approach problem definition, make trade-offs, and present their proposals. Competition alumni have taken internships and graduate employment in the attractions industry.

The competition continues to adapt and learn from year to year as it encounters various challenges, ranging from participant disclosures and media, logistics of academic absence and institutional oversight, challenges for teams to cover their costs, barriers to internship opportunities, and growing workload for production and direction of the competition. Through this evolution, the partners remain committed to sustaining and exploring the potential of the competition, whether it remains "stopgap curriculum" or transitions to formal curriculum.

3:15 pm, Stewart Center, Room 214D

Panel Discussions

Morning Panel — Engineering and Entertainment: An Academic Perspective
"In the longer run and for wide-reaching issues, more creative solutions tend to come from imaginative interdisciplinary collaboration." Robert Shiller, Contemporary Economist, Author and Nobel Laureate

In spite of many outside and within higher-education believing in the spirit of this quote, fostering, supporting, and sustaining such vital interdisciplinary collaboration, especially across domains of practice, can be challenging at best. Constraints revolving around curricular control and oversight, limited financial and human resources, lack of shared metrics/incentive systems, and more abound. Yet, for those who endeavor to engage in efforts and programming such as that found within **Entertainment/Theatre Engineering**, the nascent opportunity and personal rewards appear to far outweigh the real or perceived obstacles.

This panel, which will include faculty and administrators from a range of universities, hopes to begin to unpack a range of critical items related to nurturing the interdisciplinary nature of Entertainment/Theatre Engineering, including:

- Barriers to integrating entertainment and engineering programs, and suggestions for overcoming them.
- Fostering the fire for interdisciplinary education innovation and scholarly work.
- Promoting and sharing excellence and best-practice stories in Entertainment Engineering.
- The value of industry voice in promoting creative interdisciplinary programs.
- Exploring the ways engineering-based pedagogies can inform liberal arts education and what arts education can give to engineering students.

Moderated by Dr. Mary Pilotte, this discussion is designed to bring value to all symposium attendees passionate about the growth of this new and exciting interdisciplinary field. Ample time will be set aside to ensure discussion and question/answer is allowed to flourish.

9:45 am, Stewart Center, Room 214D

Afternoon Panel — Engineering and Entertainment: An Industry Perspective
As audiences have demanded increasingly spectacular and immersive experiences, the live entertainment industry has expanded to mean more than traditional plays and musicals on regional stages. "Live entertainment" encompasses regional and commercial theatre, to be sure, but has come to include everything from cruise ship performances to concert tours, circus acts to themed amusements, and anything in between. This expansion of the definition of "live entertainment" has occured concurrent with an increasing expectation in the level of complexity of the visual and aural landscapes that surround these events. From giant, moving stages, to complex immersive rides, from rapidly-moving lighting fixtures to large integrated networks delivering video content, meeting these challenges has required a greater reliance on engineering expertise.

This panel will include representatives from a variety of aspects of the entertainment industry, including product development, design implementation, and architectural consulting, and will attempt to discuss the place of engineering in the industry, examine existing trends in technological advancement, and explore future possibilities in the development of technologies for live entertainment.

Moderated by Professor Rich Dionne, this discussion intends to bring value to attendees who are passionate about current and future applications of engineering practices, techniques, and knowledge to the evolution of live entertainment. Ample time will be set aside to ensure discussion and questions from attendees.

2:00 pm, Stewart Center, Room 214D

Special Presentation: Robot Theatre

1:00 pm, Mallett Theatre, Pao Hall

The University of Iowa's Robot Theater Project (UIRTP) began with the goal of incorporating robot technology into the performing arts as an innovative way to promote STEM education to underrepresented students. We offer Robot Theater First-Year Seminars, use robots in demonstrations and outreach activities, offer workshops to K-12 students, and invite the public to attend live performances that showcase students' creative works. We are now moving towards the exploration of how robots can be integrated into more mainstream theatrical performances as well as the consequences of that integration.

Inspired by the popularity of dance-off competitions like *So You Think You Can Dance* and *Dancing With The Stars*, teams of Cozmo robots will challenge each other to a dance street battle, with NAO robots serving as the MC and the official judges. Opinions of volunteer human judges will be encouraged.

Presenter and Panelist Biographies

in alphabetical order

Geoffrey Akers, College of the Ozarks
Presenter
Dr. Geoff Akers is an Associate Professor of Engineering in the James P. Keeter School of Engineering at the College of the Ozarks, the only engineering program at a federally-recognized work college. Dr. Akers had a distinguished 20-year career in the US Air Force, retiring in 2016 as a Lieutenant Colonel. The majority of Lt. Col. Akers' career focused on developing and testing state-of-the-art aerospace systems. Geoff now assists in development of a multidisciplinary engineering program that provides essential engineering skills anchored with the Christian worldview to meet the needs of employers in the Ozarks and beyond. In addition to teaching at the College, he has initiated a student work station to provide acoustics engineering consulting service to campus customers, and eventually off-campus customers, as well.

Alvah Aldrich, Wenger J.R. Clancy, Inc.
Panelist
Alvah Aldrich joined JR Clancy as the Engineering Manager in 2017. His duties include managing the engineering and design of rigging components and systems for projects ranging in size from small stages to large scale performing arts centers. Prior to his role with Wenger/J.R. Clancy, he worked for Eaton developing and designing explosion proof devices and safety equipment used in industrial and oil and gas markets. Alvah has a mechanical engineering degree from Rochester Institute of Technology.

Mark Budnik, Valparaiso University
Panelist
Mark M. Budnik is the Paul H. Brandt Professor of Engineering and the Past Electrical and Computer Engineering Department Chair at Valparaiso University. He teaches courses in engineering design, leadership, and innovation. His primary

area of research is the intersection of creativity and engineering. He has served as the general/program chair for three different international conferences including those with the IEEE and the American Society for Engineering Education. Since 2016, he has worked with Disney Parks to host a new annual pedagogical conference focused on faculty development and engineering design. He holds degrees from the University of Illinois and Purdue University. Prior to joining Valparaiso University in 2006, he was an Engineering Director at Hitachi Semiconductor where he led a multidisciplinary team of engineering and support staff. He is the author of more than sixty book chapters, journal articles, and conference proceedings and the recipient of five teaching awards and six best paper/presentation awards. Dr. Budnik is a Senior Member of the IEEE and a Fellow of the International Symposium of Quality Electronic Design.

Sarah N. Chowdhury, Purdue University
Presenter

Sarah N. Chowdhury is a Graduate Research Assistant at Birck Nanotechnology Center. She is currently working on developing an eco-friendly method of plasmonic color printing which aims at resolving the crucial scenario of harmful dye color technology. This inexpensive, environment-friendly, and non-bleaching technique of color generation can be used for real-life artistic applications. She is also the Secretary of SPIE Student Chapter, Purdue University. Sarah received her B.Sc. from Ahsanullah University of Science and Technology and M.Sc. from Bangladesh University of Engineering and Technology. She is currently enrolled in the Ph.D. program at Purdue University.

Jonathan Cullison, Colorado School of Mines
Presenter

Jon Cullison is currently an Associate Professor of Music Technology at Colorado School of Mines. He holds a B.M. in Jazz Composition/Arranging, and a M.M. in Bass Performance, with a concentration in Jazz Studies. Jon has been a professional musician for 30+ years, performing and recording with a wide range of ensembles and styles covering Jazz, Salsa, Orchestral, Rock and Pop. As an audio engineer, he has recorded and mixed multiple artists, including Dan Perkins, Lorenzo Trujillo, and Belinda Womack. He has composed and arranged works for a variety of situations, including movie music with Derrick Boelter Productions and Max Wild Productions.

As an educator, Jon has taught classes ranging from Music Theory and Music History, to Electro/Acoustic Improvisation and Audio and Acoustical Engineering and Science. Mr. Cullison started teaching at CSM 10+ years ago and has built the Music Technology Program and developed the Music, Engineering and Recording Arts Minor for CSM. He also is Director of the Jazz Program at CSM, and his ensembles maintain a busy performance schedule, including public performances in Dublin and Rome, and radio performances on KUVO in Denver. He has also published educational material through XANedu for CSM classes.

Amanda Grimm, Adirondack Studios
Presenter

Amanda Grimm is a 2018 graduate of Purdue's Theatre Engineering program, double majoring in Multidisciplinary Engineering and Theatre Design and Production under the mentorship of Professors Rich Dionne and Mary Pilotte. After graduation she started her career as a Technical Designer for Adirondack Studios in Argyle, NY. During her time at Purdue, Amanda was able to benefit from the innovative combination of her theory–intensive engineering classes and the hands–on opportunities in the theatre department. Since graduating she has been able to put these skills to use in the industry, doing design work on amusement park projects ranging from structural show set elements to small scale automation.

Robert Klimek, Colorado School of Mines
Presenter

Dr. Robert Klimek, BA, MDiv, MA, DA is a CSM Teaching Professor, musician, composer and clinician in ethnomusicology. Some of his past teachers include Aaron Copeland, Philip Glass and Donald Keats. His works can be heard worldwide and can be found in over 100 music collections. He has been a featured artist on a Grammy nominated album, as well as final nominee for the National Booksellers Gold Medallion Award. Currently, he is the director of the Music and the Performing Arts program at Colorado School of Mines, which offers a minor in Music, the Recording Arts, and Technology. The program successfully produced its first full album in 2012, and was awarded the Recording of the Month (December) by the Independent Broadcasters Association. Dr. Klimek and Dr. Skokan have been leading international trips with CSM music/engineering students. Each of the experiences emphasized both sides of the students' skill set (engineering/music). All trips included music performances; ethno-music instruction; engineering lectures; industry tours; and community service projects. Dr. Klimek's hope, through these international experiences, is to create a pathway upon which the CSM student realizes that his/her technical field is an "art form." This art form enhances and enlivens both the student and the peoples and cultures visited.

Dan Lisowski, University of Madison-Wisconsin
Panelist
Professor Dan Lisowski is a faculty member in the Department of Theatre and Drama, Head of the Theatre Technology MFA specialization, and Director of the Entertainment Technology Innovation Lab (ETIL). While pursuing his undergraduate degree from the University of Wisconsin-Madison (BS, Theatre and Drama: 2003), Dan was a member of two Rose Bowl Championship teams (Football 1997-2000). Dan received his terminal degree from the Yale School of Drama (MFA, Technical Design and Production, 2006) and worked professionally as an entertainment design engineer until he returned to join the faculty at UW-Madison in 2009. His primary research interests include entertainment automation control systems and network-based functional safety. Dan and his wife, Meghan (BA, 2003), have five "badger-loving" children.

Verda Beth Martell, DLR Group
Panelist
After 22 years as a technical director, Beth has taken her end-user expertise to consulting. In 2016, she joined DLR Group | Westlake, Reed, Leskosky, a national integrated design firm with architects, engineers, designers, and specialists all under one umbrella. Beth has had a hand in designing more than 20 performing arts facilities, including large professional venues, highly tuned recital halls, university performing arts complexes, and expansive high school theatre facilities. Prior to her move to architecture, Beth was the Chair of Scenic Technology for the Department of Theatre and the Technical Director for Krannert Center for the Performing Arts at the University of Illinois. Beth is a current member of the board of directors for the United States Institute for Theatre Technology (USITT) and chairs the Essential Skills for Entertainment Technicians (eSET) Council. She has presented more than two dozen sessions and workshops, including the Physics of Theatre series with her research partner (and husband) Dr. Eric Martell. In 2015, she and Eric published *The Physics of Theatre: Mechanics* as a resource for technical directors, riggers, and automation specialists. Along with her theoretical work developing mathematical models to predict the action of theatrical machines, Beth also designs theatrical automation systems, and scripts/programs in multiple languages, including ladder logic, LISP, and the National Instruments graphical programming environment LabVIEW. She is an ETCP Certified Rigger - Theatre and an ETCP Recognized Trainer. Beth holds an MFA in theater technology from the University of Wisconsin - Madison and a BS in theatre from Illinois State University.

Amanda S. Mayes, Purdue University
Presenter
Dr. Amanda Mayes is the Manager of Education for Purdue Convocations. She oversees programming for family and youth audiences, outreach activities, and curricular integration at the K-12 and collegiate level. In addition, Dr. Mayes runs all research initiatives at Convocations and serves as a research consultant for the ArtsKC Regional Arts Council. Her research interests include academic and intrinsic impacts of arts experiences, program assessment, professional development, improving cultural competency, and arts advocacy. Previously, Dr. Mayes managed an NIH funded investigation of media's impact on health related behaviors in college women and was a visual arts teacher for over a decade. She has given presentations of her teaching and research at regional, state, and national conferences. She holds a PhD in Curriculum and Instruction from Purdue University, a MA in Visual Arts Education from Purdue University, and a BS in Visual Arts Education from Indiana State University.

Katherine Metzler, SUNY Buffalo
Presenter
Katherine Metzler is an emerging professional from Buffalo, New York. She attended the University at Buffalo, SUNY, graduating in 2019 with dual degrees: Mechanical Engineering, BS and Theatre, BA with a concentration in design and technology. She intends to use both degrees to work on complex projects, and help with technological and safety advancements in the entertainment industry. Within the undergraduate theatre program, she worked as the Technical Director for three department productions, but also cross trained and held the role of Set Designer, Lighting Designer, Sound Designer, and Master Electrician, among other assistant roles. Within the engineering program there were multiple classes with a lab component or semester long group projects which trained future engineers in the hands on and collaborative aspects of the job more than just pages upon pages of maths. Ultimately she

attempted to cultivate the useful knowledge from each discipline to create a unique blend of skills. Having just come out of these two separate programs which at this stage, are beginning to encourage, but don't necessarily foster interdepartmental cross over, she is excited to join the conversation about the convergence of the fields on the educational and professional levels.

John Persichetti, Colorado School of Mines
Presenter

John Persichetti, BS, MS Chemical Engineering is a Mines Teaching Associate Professor, Assistant Director for the Engineering, Design, and Society Division, Director of the Capstone Senior Design program for approximately half of the Mines graduating engineers (~500 students per year in a multidisciplinary program), and Director of the general BS in Engineering degree at Mines. John is also a choral musician, member of an English Handbell choir, and involved in community theatre as set designer and technical director for a half-dozen productions. Intertwining his engineering background, creative engagement in the classroom, and passion for the performing arts, John likes to bring an added dimension to both his community performances and to the way engineers think about creative problem solving. The BS in Engineering degree program that he directs allows students to pursue a passion to help enliven their career pursuits. One of the prescribed and transcripted areas of study for the degree includes a focus in Music, Audio Engineering, and Recording Arts, allowing students 18 semester hours of course study dedicated to any of these aspects of the performing arts and advising on appropriate engineering courses to support the technical dimension of the arts.

Donna Riley, Purdue University
Panelist

Dr. Donna Riley is Kamyar Haghighi Head of the School of Engineering Education and Professor of Engineering Education at Purdue University. Dr. Riley joined Purdue in 2017 from Virginia Tech, where she was Professor and Interim Head in the Department of Engineering Education. From 2013–2015 she served as Program Director for Engineering Education at the National Science Foundation (NSF). Riley spent thirteen years as a founding faculty member of the Picker Engineering Program at Smith College, the first engineering program at a U.S. women's college. In 2005 she received a NSF CAREER award on implementing and assessing pedagogies of liberation in engineering classrooms. Riley is the author of two books, *Engineering and Social Justice* and *Engineering Thermodynamics and 21st Century Energy Problems*, both published by Morgan and Claypool. She is the recipient of the 2016 Alfred N. Goldsmith Award from the IEEE Professional Communications Society, the 2012 Sterling Olmsted Award from ASEE, the 2010 Educator of the Year award from the National Organization of Gay and Lesbian Scientists and Technical Professionals (NOGLSTP), and the 2006 Benjamin Dasher Award from Frontiers in Education. Riley earned a B.S.E. in chemical engineering from Princeton University and a Ph.D. from Carnegie Mellon University in Engineering and Public Policy. She is a fellow of the American Society for Engineering Education.

Ann Shanahan, Purdue University
Panelist

Professor Shanahan's research interests and teaching specialties include directing, gender and theatrical space, and theatre and social change. A scholar-artist, her recent publications include essays on directing practice written as the founding co-editor of the Peer-Reviewed Section of the SDC Journal, the official publication of the Stage Directors and Choreographers Society. She is the editor of *Landscapes of Consciousness: Meredith Monk, Robert Wilson and Richard Foreman*, the 6th volume in a new series, *Great North American Theatre Directors* (Bloomsbury Methuen, 2020 forthcoming).

Professor Shanahan has presented numerous papers on acting and directing pedagogy at the Association for Theatre in Higher Education (ATHE) and Comparative Drama Conference (CDC), and on gender and performance at the National Women Studies Association (NWSA) Conference. She served as Focus Group Representative for the Directing Focus Group at ATHE 2014-16, and as the Vice President for Conference 2018, theme: "Theatres of Revolution: Performance, Pedagogy and Protest."

Professor Shanahan served as dramaturg for the national touring production of *Angels in America, Parts I and II* (dir. Michael Meyer), *Third* (dir. Sarah Gabel) and *The Mistress Cycle* (dir. Kurt Johns) at Appletree Theatre, for Rivendell Theatre Ensemble's productions of *Mary's Wedding* (dir. Mark Ulrich), *Falling: A Wake* (dir. Victoria Delorio) and *The Electric Baby* (dir. Tara Mallen), and for Red Twist Theatre's production of *A Delicate Balance* (dir. Steve Scott).

Catherine Skokan, Colorado School of Mines
Presenter

Dr. Catherine Skokan, BSc, MSc,PhD – Geophysical Engineering, is an associate professor emerita at the Colorado School of Mines and is the first woman to receive a graduate degree from this institution. Her technical interests include volcanoes, geothermal and energy resources, groundwater resources, and humanitarian engineering. Dr. Skokan has traveled extensively with student groups and she has led humanitarian engineering projects to the Americas, Europe, and Africa. She has also conducted workshops in Italy, Colombia, Tanzania and Zambia. Dr. Skokan is a regular lecturer for the Road Scholar Program where she lectures on cruise ships. Her music interests include playing violin with the CSM orchestra, bassoon with the CSM band, and erhu with the CSM Chinese Ensemble as well as performing with chamber groups outside of CSM. With Dr. Robert Klimek, Dr. Skokan has led trips with Colorado School of Mines students over Spring Break. As a window into culture, Drs. Klimek (Director of Music) and Skokan (Engineering) organize trips to include technical tours and music experiences – both performance and as an audience. These trips have taken students to Italy, Peru, Jamaica, Ireland and Vietnam. With student groups, her passion is for travel and to share with others our beautiful world.

Denise Szecsei, University of Iowa
Presenter
Denise Szecsei teaches Mathematics and Computer Science at the University of Iowa. She received undergraduate degrees in Physics, Chemistry, and Mathematics from the University of Redlands, and a Ph.D. in Mathematics from the Florida State University. She enjoys keeping up with new technological developments and incorporates new technology into her classes and research activities. She has been working with NAO humanoid robots for the past six years, and Cozmo for two years. She has designed robot dance and theater classes for students with a variety of interests and backgrounds, and is excited to watch how people of all ages express themselves through these robots.

John C. Tompkins, Purdue University
Presenter
John C. Tompkins serves as the lecturer in technical communications for the Lyles School of Civil Engineering at Purdue University where he teaches the core writing and speaking classes for the school. He received his BA in English from the University of Colorado at Colorado Springs in 2002 and his PhD in English from Purdue University in 2013.

Nic White, College of the Ozarks
Presenter
Nic White is currently a junior in the College of the Ozarks' engineering program. He began working for the college's Engineering Department in August of 2017 as a student worker. Nic tutors for math and engineering classes, as well as how to use equipment and software; such as 3D printers, laser engravers, and CAD software. Nic has most recently begun helping Dr. Geoff Akers with work in the field of acoustics by using acoustic software to model and analyze the acoustic environment of facilities. Nic White plans on graduating with a BS in Engineering in May 2020 and continuing towards an electrical engineering career.

Kathryn Woodcock, Ryerson University
Presenter
Dr. Kathryn Woodcock is Professor at Ryerson University in Toronto and director of the THRILL Lab, involved in unique extracurricular training, research, and knowledge mobilization activities focused on human factors of amusement rides and attractions. She studies accident and error analysis, task demands, and interface design, pertaining to guests, operators, and inspectors. Her research, innovation, and service have been published in over 75 peer-reviewed chapters, journal articles and conference papers and over 200 other presentations and publications for both industry and professional audiences. Dr. Woodcock is a member of TEA, ASTM Committee F24, Ontario TSSA Amusement Devices Advisory Council, Global Safety Committee of IAAPA, and Board of Directors of the Canadian National Exhibition, consults to designer/manufacturers and owner/ operators, and regularly instructs at AIMS and NAARSO industry seminars. She chairs the inaugural Themed Experience and Attractions Academic Symposium, and leads the international Rider Eligibility Task Group for ASTM Committee F24. She is a registered Professional Engineer, IAAPA Certified Attraction Executive, Canadian Certified Professional Ergonomist, and Fellow of Association of Canadian Ergonomists. She earned Bachelor and Master's degrees in Systems Design Engineering at University of Waterloo, and PhD in Mechanical and Industrial Engineering at University of Toronto, all specializing in human factors engineering.

Beauty in Engineering and the Performing Arts

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Abstract— **This paper outlines the intersection of the Performing Arts and Engineering, and methods for successful inclusion of the arts in an engineering curriculum. Through a discussion of the classic ideas of Beauty and Art, parallels are drawn between the engineering design approach and the composition / creation approach common in the arts as a means to find common ground for engaging engineering students more fully into the arts as a life-long passion and possibly a career path.**

Keywords—"engineering in the arts", "engineering design and composition", "music, theatre, and engineering, beauty

I. INTRODUCTION

It wasn't that many years ago that Engineering Faculty had very little to do with Liberal Arts Faculty; they viewed their spheres of interest at opposite ends of the spectrum. It was acceptable for the graduating engineer to go out in the world with the perspective that being able to build, modify or create something was all that mattered [1]. After all, the job of an engineer often is to design products or systems based on the technical skill gained through their education. The engineering design process [2] has been represented in many ways but can generally be distilled into an iteration of elements that include envision/design, construct, evaluate, and cycle back through redesign until a polished final product is achieved. The musical composition process is very much the same. Putting up a theatrical production likewise follows an envisioned approach that with the keen eye of a director is subject to iterative manipulation of staging, blocking, effects, all to fit within the constraints of a particular stage, abilities of those involved, and budget. And, we cannot disregard the same in the visual arts. History has shown us that the masters of creative genius were both "engineer" and "artist" – those who gave us the engineering marvels of the Egyptian Pyramids, the beauty of Michelangelo's Sistine Chapel Hand of GOD, the emotional delivery of Les Misérables, of course The Beatles, and the many designs of musical instruments and performance areas that support the arts. Why is it then that these creative endeavors are often seen as being at opposite ends of the educational spectrum? Both the engineer and the performing artist strive for essentially the same goals of beauty (which the engineer may think of as aesthetics in design) and achieving desired functionality. Our technical university has made a concerted effort to allow our students to see beauty in many different forms that also achieve a required functionality.

II. BEAUTY

In many of their creations, both engineer and artist strive to create beauty. But what is BEAUTY? The dictionary[3] defines beauty as the quality present in a person or thing that gives intense aesthetic pleasure or deep satisfaction to the mind or the senses. The idea of beauty is not just a physical appearance of a person or object. Rather, it is an understanding that gives some perceptual experience to one's physical senses, intellect, and moral appreciation. Beauty in a person or object provides perceptual experiences of happiness, contentedness, or completeness. Beauty has traditionally been counted among the ultimate values, alongside goodness, truth, and justice [4]. Beauty can be thought of as a balance and harmony with nature. A finely engineered building, this is above canon for the sake of those inside it, can be considered morally "upright" for those whom it serves. It shows not only symmetry but also a rightful well-made-ness to those who inhabit it.

Let us inspect beauty in art. Many argue that art cannot be defined. Art [5] is often considered the process or product of deliberately arranging elements in a way that appeals to the senses or emotions that vary from person to person. It encompasses a diverse range of human activities, creations, and ways of expression, including music, literature, film, sculpture, and painting.

A dictionary definition of engineering [6] includes terms such as design and build, but also compose, mold, frame, fashion, and shape. Many engineering design approaches deliberately have the same approaches as displayed in art: achieving an overarching outcome through the collection and arrangement of what may otherwise be seen as unrelated elements of equations, physical properties, social impact, and stakeholder engagement.

III. ABOUT OUR UNIVERSITY

At the Colorado School of Mines (Mines) a group of faculty members have cooperated in working on the intersection of the Performing Arts and Engineering, and methods for successful inclusion of the arts in an engineering curriculum. Our panel consists of two engineering and two music professors all of whom have worked closely in collaboration at the university. Mines [7] is a public research university devoted to engineering and the applied sciences, and unique in that almost all degrees offered are technical degrees. Our degree offerings include the traditional earth sciences which serve as our historic foundation, as well as engineering and science/math arenas. These include geologic, geophysical, mining, and petroleum engineering as well as materials science (metallurgy), computer science, mathematics, and chemistry. Degrees are also offered in the traditional engineering topics of civil, mechanical, electrical, and chemical engineering, to name a few. Our students must complete a liberal arts component in their engineering curriculum and many chose the performing arts to partially fulfill this requirement. The performing arts fall under the non-technical department umbrella called Humanities, Arts, and Social Sciences (HASS). This department offers courses in language, international affairs, ethics, music and performing arts, literature, and philosophy. A wide range of music experiences are offered: band, orchestra, jazz band, choir. We also offer individual music instruction, classes in music theory, composition, and history. In addition, our students can receive a minor in Music Technology, or integrate a focus in music technology as part of a general B.S. in Engineering degree. Recently we have added a theatre class to augment our performing arts curriculum.

As a highly selective school, one in ten applicants enroll at Mines. The student body includes about 4900 undergraduate and 1500 graduate students. Almost 30% are female and 11% are international. Minorities count for 19% of the student population. Our performing arts classes draw from the entire student population and often attract higher percentage of females than the school average. Our music classes are popular, usually fully enrolled and often have a waiting list. The class sizes range from 35-45. Our band has 115 students, orchestra has 78 students, and choir with 75 students.

IV. CURRICULAR OPPORTUNITIES

Along with our technical courses central to the major of each of our students, we offer an array of courses to fulfill the liberal arts requirement. Many students choose performing arts courses. We purposefully integrate the performing arts with technical topics in both liberal arts as well as engineering design courses. Some students are motivated to go beyond the required liberal arts component seeking a minor in music or music technology.

A. Music Technology

Our Music, Engineering, and Recording Arts Minor (MERA) is designed for students interested in the crossover between music and related engineering skills. Specifically, students in the minor program must take five required courses: Audio/Acoustical Engineering and Science, Music Technology, Music Traditions of the Western World, Real World Recording Seminar, and Music Technology Capstone. An additional three credit hours in either music theory, band, choir, orchestra, or jazz band are also required. A similar integration of music technology and engineering studies can also be achieved through a more integrated approach of a B.S. in Engineering (BSE) with a Focus Area in Music, Audio Engineering, and Recording Arts – the 'music' component is thus an integral part of the engineering degree curriculum. Emphasis within the minor or BSE creates an opportunity for the student to research/experience the impact of engineering on music as an art form, music as a technology driver, and music as an industry. Throughout, students are exposed to the refinements and developments that engineering has created in the field of recording, production, sound reinforcement and product design, as well as, the interplay between the arts and technology. The discovery of connections between current music and engineering practices is stressed. The final outcome is a skilled and informed studio technician/musician in present day studio conditions.

The important idea observed in these classes is the concept that development of art requires technology, and that technology requires art to have a target to advance toward. The technical advancements in the recording industry evolved to allow for the correction of "Human Error." The technology allowed us to strive towards achieving an ideal, an "immortal" product. When phrased to our engineering students in these terms, our students begin to understand how both design and art can express the concepts of beauty. If we expand this to other artistic fields, the artistic impact of cinema, theater, dance have evolved due to technological innovations such as intelligent lighting, stage technology (flying harnesses and rotating stages), and emerging holographic presentations.

Again, the technology allows the artists to achieve a goal that was previously unattainable, and the art asks the technology to grow and evolve to meet this demand.

B. Theater Course

Recognizing the natural extension of the music-engineering integration into another performing arts sector, that of theatre, in Spring 2019 a new series of courses in the theatre arts was launched, the first being Theatre Technology, Production, & Performance. The course was fully enrolled at 30 students within minutes of being opened for registration. This course starts with the basics of theatre space, tools and safety, production analysis, the scenic design process, all of which was transferred into a final performance, showcasing the pathway of engineering technology into performance. The engineering aspects came to fruition and sparked a creative outlet for these students when set and staging moved into electrical theory, stage lighting, sound design, mechanical contraptions, and even costume design. Since the inception of this first course, an additional offering in Acting, Locution and Public Presentation is now included in the Fall 2019 schedule. Acting through realism is a natural fit for engineering students to gain the confidence to present to clients and large audiences. This class also filled within a few minutes of open registration.

C. Engineering Design

At Mines, students are exposed to the Engineering Design Process beginning in their first year through the Cornerstone Introduction to Design course. This course leads students through the concept of open-ended problem solving, teamwork, technical solutions, and non-technical constraints. A good engineering design is seen as "beautiful" to both the designer and the customer.

Throughout the curriculum, generally in studio courses, the engineering design process is reinforced. Finally, during the senior year, the students participate in a two-semester sequence of Capstone Design.

A good engineering design is seen as "beautiful" to both designer and customer/consumer. A typical mistake in the design process is for the designer/engineer to design what they see as being functional or as meeting their personal view of the needs of the project. The Mines' design programs emphasize user input and ancillary stakeholder engagement. The term "beautiful", as relates to design in the theatre space, is based on its definition of "pleasing the senses or mind aesthetically" or "of a very high standard; excellent". Emphasizing and incorporating stakeholder engagement is an exercise in having the students pick apart and assess what the audience hears, sees, and senses environmentally (temperature and air). The theatre course is an intentional merging of engineering design instruction within the confines of and understanding of the theatre space and audience as key stakeholders. This course structure allows us to actively engage and immerse our engineering students instead of having just an elective course in theatre. We believe that in doing so, we are actively integrating the arts and engineering.

To illustrate, a past senior design team of five students were tasked to design and build a theatre set piece inspired by a rotating, multi-room depiction of a two-story house, both interior and exterior, as seen in a production of Noises Off. Criteria given to the student design team, beyond the general set concept, were that it be a robust modular and sturdy piece, and that it be generic enough to be usable in multiple theatre productions. The main engineering challenge was adapting it to fit in a storage space the size of a shipping container and that it be portable enough to be moved to various performances locations in the campus community by fitting it into the bed of a pickup truck and then fit through a double wide door. Making the set piece modular addressed this space constraint and goal of robustness. Overall, the project required attention to mechanics of materials and the structural systems of mechanical or civil engineering. The final design document provided detailed construction drawings and cost analysis and required showing proof that the design met local building codes. The team also built a full-scale prototype to test the mechanics of materials, modularity, portability, and ease of stage set-up.

Another senior design project was the design of a lighting and sound support grid structure to be used in a new black-box rehearsal and performance space. The intention was to determine the weight and load distribution for suspension from existing ceiling/roof structural members under load from a variety of lighting options (theater and stage style lighting along with additional house lighting), AC junction boxes, speaker arrangements on the same grid, to accommodate performances given from four areas of the floor space with associated audience arrangement in part or all the remaining space. The grid location, and associated speaker locations needed to work around existing ceiling acoustical elements. The load analysis showed that the existing roof supports were inadequate on their own and would require reinforcement. The student team also determined the electrical needs concentrated at a light/sound booth location and wiring demands when tied into an existing 3-phase circuit panel.

D. Travel

In an initiative to expand our engineering students' perspective and to help them understand that culture can contribute to the success or failure of engineering and scientific projects, the President of Colorado School of Mines, Paul Johnson, has encouraged international experience for all of our students. Mines recognized that our graduates will be working in a multi-cultural and interconnected world, often as agents of change, and thus need to gain cultural awareness of the people and communities where they will be working [8]. In response to this school-wide initiative, we have established a travel program that includes both engineering and performing arts components. This unique international travel program, headed by Drs. Klimek and Skokan, received the 2018 Michael P. Malone International Leadership Award from the Association of Public and Land-Grant Universities in recognition of outstanding accomplishments in bringing global perspectives to higher education.

For the last seven years, students have had the opportunity to investigate cultural connections through international travel during spring break. When the demand is great enough, we offer a semester-long preparatory area-study class for credit. If a credit class is not offered, the students meet regularly during the semester prior to the trip to learn about the history, culture, government, and educational systems of the country that we will visit. On average, 50 students take the opportunity to embark on a 10-day trip. Our travels to date have included Italy, Ireland, Jamaica, Vietnam, Portugal, and Peru. In each trip, students have experienced performance opportunities and have visited engineering schools and industries. Our industry visits have varied from the Tuff Gong Recording Studio in Jamaica, a luthier specializing in Baroque string instruments in Rome, a working lead/zinc mine in Ireland to Proctor and Gamble diaper assembly plant in Vietnam. It was interesting that in all industry visits, both the technical and aesthetic components were emphasized. Our performance opportunities were both as performers and as audience. For example, in Peru, our small ensemble instrumental students gave concerts at a home for the elderly, a school for the handicapped, a university experimental mine, a rural village, and a minerals museum. In Poland, our vocal ensemble gave concerts at a salt mine, at a home for the elderly, and at an elementary school. In Vietnam, our students attended a multi-media performance and the historic opera house in Ho Chi Minh City. However, one of the most transformative experience, as reported by our students, has been their connection with their peers at universities. Another example of the transforming results of this type of travel experience can be observed from a trip to Rome. One Civil Engineering student, Martha, at St. Peter's Basilica in Rome, while awaiting to play in performance, found herself idly analyzing the marble wall panels near her seat. Then she stopped herself abruptly, explaining to us later, "I'm accustomed to looking at materials for what they are. For once in my life, I needed to look up and realize the great building I was in, the great building that I had a chance to perform in! I never thought this day would ever happen for me."

V. CONCLUSION

Both Engineers and Artists have the same goal: the communication of beauty in its classic sense. We at the Colorado School of Mines have given our technical students opportunities to practice the arts through music and theater performance, as well as, music technology experiences. Our goal is that our students see beauty in all that they do. Our goal is that they feel empowered in their technical field through a realization of how they design and present their work for the betterment of the community around them. We want to graduate a polymath [8]: a term we translate as the non-traditional artist/engineer.

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PAPERS

Acoustic Engineering Workstation at the College of the Ozarks

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Abstract— **The College of the Ozarks is developing the ability to provide acoustic engineering services to customers on and off-campus. The College is the only federally recognized work college with an undergraduate engineering program, which means students do not pay tuition and are assigned workstations on campus to help defray expenses and to generate income for the College. This paper addresses the purpose and administration of the workstation and how it is unique from other service-learning programs, the perceived benefits to the student workers and the engineering program, recent workstation accomplishments, lessons learned, and future plans.**

Keywords—acoustics, engineering services, work college

I. INTRODUCTION

The undergraduate, multidisciplinary engineering program at College of the Ozarks (C of O) began in 2016 and plans to seek ABET accreditation after graduating its first engineers in May 2020. The school is a private Christian, liberal arts college and is a federally recognized work college. As stated by the college president, Dr. Jerry Davis, "C of O is unique among higher education institutions in America: no tuition is charged, all students work on campus, debt is openly discouraged, and no federal, state or private loans are made [1]." Of incoming students, 90% have demonstrated financial need. C of O is currently ranked #3 in Regional Colleges Midwest by U.S. News and World Report [2].

All full-time students work 280 hours per semester at on of about 80 workstations on campus in lieu of paying tuition. Some of these workstations allow the College to avoid costs, such as custodial, landscaping, construction, cafeteria, and the information technology help desk. Other workstations on campus are dedicated to generating income, such as Edwards Mill, the Fruitcake and Jelly Kitchen, and the Keeter Center, a top-rated restaurant and a "2019 Travelers' Choice" small hotel [3]. The College also manages pork, dairy, and beef farms. These farms provide some income to offset expenses, though their primary purpose is to provide vocational learning opportunities for agricultural students.

Following the farms' approach to vocational learning, the Engineering Services workstation began in the spring semester of 2018 with one engineering student supervised by an engineering faculty member. The long-term goal is to provide engineering services to the local community, with enough paying customers at least cover the costs of the workstation. More important than generating income for the College, the mentored experience gained by undergraduate engineering students providing those services is designed to complement their academic program.

This paper first discusses the unique aspects of the Engineering Services workstation and its objectives. The approach to providing practical engineering and project management experiences is then presented. Initial experiences on the first two projects of the workstation are discussed next. Lessons learned and future plans for the workstation and the conclusions section complete the paper.

II. ENGINEERING SERVICES WORKSTATION

Workstations at C of O help students develop strong work ethics, as well as effective communication teamwork skills. The Engineering Services workstation also seeks to integrate practical engineering design experience by providing engineering consultant services. The goal is for an engineering faculty member as the workstation supervisor to function as a technical program manager and the student workers to fill the roles of project engineers.

The value of learning experiences beyond the lectures in the classroom is well-recognized. The Engineering Accreditation Commission of ABET requires engineering programs to provide "a culminating major engineering design experience" [4]. As a result, many engineering programs, including the program at College of the Ozarks incorporate capstone courses to provide project-based student experiences, which often include real-world design experience incorporating material from the courses they have taken to that point.

Some engineering programs have integrated significant project-based courses into their undergraduate programs. "Project-based learning is a comprehensive approach to teaching and learning that is designed to engage students in the investigation of authentic problems." Two of many examples of programs with significant project-based course content are Massey University, which has courses incorporating project-based learning across the four years of the engineering program [5], and the Iron Range Engineering (IRE), which is a 4-year collaborative engineering program accredited through Minnesota State University, Mankato. "By interfacing with local industry through a unique project-based approach, IRE continues to bring the learning experience closer to engineering practice than ever before

[6].”

Some programs have added a community focus to the projects in project-based learning. One of the most recognized is EPICS founded at Purdue in 1995, whose goal is “development, design, and support of technology-based solutions to meet needs in the local and global communities [7].” Another program at UMass Lowell is Service-Learning Integrated throughout the College of Engineering (SLICE), which incorporates service-learning into at least one course every semester in the core curriculum of each of their engineering programs [8].

Federal work-study jobs seek to give students relevant experience outside the classroom and are a popular approach for students with financial need to help fund their academic pursuits [9]. The Work Colleges Consortium (WCC) carefully distinguishes between federal work-study programs and workstations at the eight federally recognized work colleges. All work college students, not just those with financial need, are required to work a set number of hours, and the work contributes directly to the operation of the college. All resident students participate in the work-learning service program and “are given responsibility, counted upon, gain valuable work experience, while reducing the cost of education [10].” These contributions include cost-avoidance, such as administrative, maintenance, and construction, as well as revenue generation, which is unique for each institution. Each student worker is formally evaluated each semester and provided individual feedback.

The Engineering Services workstation is distinct from project-based and service-learning courses. As with other workstations within the WCC, no academic credit is assigned and a set number of hours per semester are prescribed. Unlike the federal work-study program, the hours students work in a workstation are credited toward tuition instead of a paycheck. Other distinctions of the engineering workstation are that projects are not limited to multiples of a semester, and the small size of the workstation ensures one-on-one or one-on-a-few mentorship between the faculty supervisor and student workers and job-like interaction between student workers.

Students recognize the opportunity to apply their budding engineering expertise, so the Engineering Services workstation assignment is highly sought after. To date, one hand-picked student has been allowed to participate with a planned addition of one part-time student is in the fall of 2019.

A. Establishing the Workstation

The Engineering Services workstation was envisioned to be part of the engineering program from its inception. The Program Director recognized the value of service learning and a soup-to-nuts engineering design experience. As mentored workstations are integral to work colleges and serving others is integral to the Christian worldview, a workstation focused on serving on and off-campus customers using the engineering design process seemed a natural fit.

An engineering advisory board (EAB) consisting of engineers from industry in the region is also key to defining objectives and methods of the multidisciplinary engineering program at C of O. The EAB recognized the similarities in purpose between the College’s dairy, beef, and hog farms for the agricultural students and what an engineering services workstation could provide engineering students. The farms afford students a practical farm experience in a supervised environment. Milk, beef, pork, and live animals are sold to offset operation expenses. Dubbed the “engineering dairy farm”, the EAB envisioned an engineering services workstation employing a significant number of engineering students. The workstation could provide tiger teams for small projects, such as designing a replacement motor drive circuit for an old milling machine, as well as larger teams with longer-term projects, such as an aquaponics system for Christian mission organization in Ecuador. The goal would be for the workstation to be self-sustaining financially, with a mix of paying nonpaying customers and not compete directly with local industry.

Currently, C of O has more work to do than student workers available. The cost model prevents significantly increasing enrollment, as students do not pay tuition. For this reason and the current workload of the engineering department as they develop new courses, order equipment, move into new facilities, and prepare for accreditation, the workstation started small.

B. Acoustics Focus

College of the Ozarks is near Branson, Missouri, which has a large entertainment industry. Acoustic engineering is in demand by theaters, local churches, as well as manufacturing companies desiring to reduce machine noise within the facilities. As a result, the Engineering Services workstation was initiated with an acoustics focus.

A Work College Consortium (WCC) grant was pursued to provide seed money for the hardware needed for acoustic measurements. The grant application was used to lay out the purpose and scope of the workstation. In addition to applying for funding, the College process of approving the application gained buy-in from the Dean of the College, as well as the Dean of Work. This buy-in effectively established the Engineering Services workstation.

When the WCC grant was approved an NTi XL2 Audio and Acoustic Analyzer with the Extended Acoustic Pack and a Level 1 measurement microphone were purchased [11]. Beginning the spring semester of 2018, a student worker was shared between the engineering department and the engineering services workstation. About 10-12 hours per week of the student’s time was spent with engineering services and 3-5 hours per week with the department grading or helping the nascent program prepare for classes and labs and move into the new Dee Ann White Engineering Center.

The supervisor of the engineering services workstation is an electrical engineer with background in radar and had no significant experience with acoustics. As a result, the supervisor and student worker have had the opportunity to learn some of the technical aspects of the workstation together. A member of the program’s EAB with acoustics expertise has provided free consultation and mentorship for both the faculty and student.

III. LEARNING STRATEGY

The primary objectives of the workstation are to provide the student workers with opportunities to implement the engineering design process and to develop professional skills. The strategy to achieving these objectives has effectively created an engineering consultant experience for the student workers. As previously mentioned, the supervising faculty fills the role of project manager, while the student workers are the project engineers.

A. Technical Approach

Beginning with the first semester "Introduction to Engineering" course, students learn the fundamentals of the engineering design process and gain experience managing a project as a team. These fundamentals are further developed through the engineering curriculum, culminating with the senior capstone sequence, a two-semester engineering design team experience. In parallel with the engineering courses, Engineering Services workstation aims to give selected students the opportunity to participate in practical experiences with engineering design and project management, while providing needed engineering services to campus and community customers.

The first objective of a workstation providing engineering services is to allow students opportunities to practice engineering design in an environment where failure is more acceptable than is often the case in industry. The student is stepped through the engineering design process as seen in Figure 1, which is a tailored version of Kosky's engineering design process [12] presented in "Introduction in Engineering". The dashed lines represent content that has been added to Kosky's figure, and the titles of the blocks have been modified to fit the design process of the Engineering Services workstation.

Defining the problem and understanding its context is the first step in engineering design. Once a customer has been identified, the faculty supervisor and student worker team meet with the customer to understand the objectives and scope of the project, as well as make physical measurements of the facility and perform some preliminary acoustic measurements. The Engineering Services team then meets to develop a plan forward, which includes developing a project description, modeling the facility in software, and writing a proposal with a test plan and an initial project schedule.

Modeling the facility in software to establish the baseline performance and validating that model is key to the design process in many engineering disciplines. A baseline model of the acoustic environment is also in integral step to determining what approaches to improving the acoustics will be most effective.

Steps 2-4 are accomplished as analysis of data from the simulated facility and physical facility are compared, the model is refined, and then the improvements are then recalculated to dictate if those modifications made a difference. These improvements typically include a mix of acoustic absorbers and diffusers. After the supervisor and student worker agree on one or more potential solutions, a presentation is prepared for the customer, which is step 5 of the process. The customer presentation includes the estimated cost, schedule, and performance for each of the potential solutions. Together with the customer, the acoustic team selects the best-value concept. The customer determines the definition of "best value", as the facility and resources to make the modification are theirs.

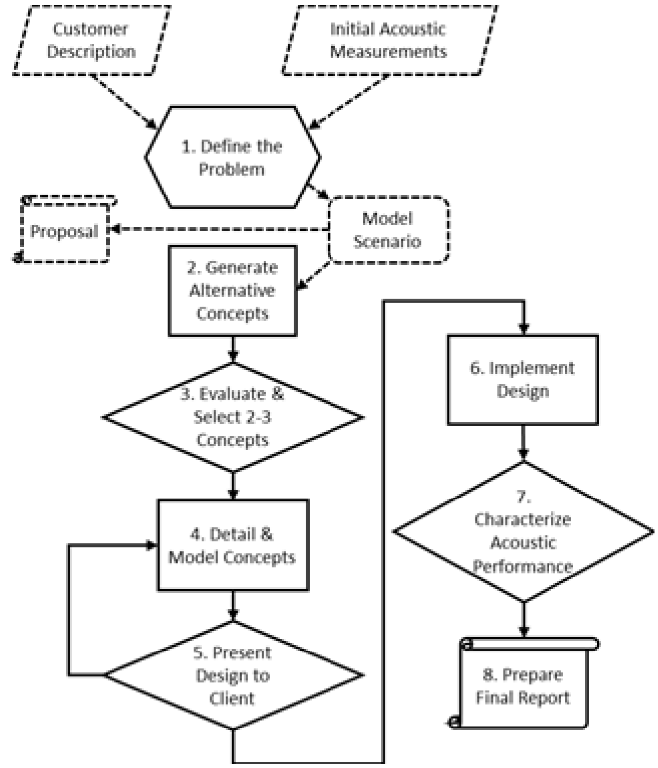

Figure 1. Tailored Kosky Eningeering Design Process [12]

Once a concept has been chosen, the design is refined. This refinement often includes optimizing the locations, as well as sizes, shapes, and number of the absorbers and diffusers. Facility modifications are also possible but less desirable from a cost and schedule perspective.

The final design is prototyped in software and reviewed with the customer before implementing in the facility, completing step 6. Once the solution is implemented, measurements are conducted to validate performance, step 7. Step 8 concludes the project as a report is written and delivered to the customer.

B. Project Management Approach

As project engineer, the student worker writes the proposal and final report, presents the design options to the customer, and regularly interfaces with the faculty supervisor. The student worker tracks progress, meets with consultants, allocates resources, and is engaged in managing time throughout the project. These tasks are also covered in the senior capstone sequence of the engineering program and put into practice in the Engineering Services workstation, usually before the student has taken the capstone courses.

An initial schedule is developed for the proposal and illustrated in a Gantt chart developed in Microsoft Project®. The student worker and faculty supervisor review it weekly during team meetings. Understanding concepts such as learning curves helps the student determine how to estimate the length of unfamiliar tasks, such as learning to use new software to model acoustic environments. Balancing duties outside of the project and focusing on certain tasks in order to maintain deadlines forces the student to think several days and even weeks ahead to meet the requirements of the client in a timely order.

Weekly team meetings simulate the professional environment, including sometimes being cut short due to outside influences. Each week the student discusses what the accomplishments and challenges are of the previous week and the plans for the next week. Notes are taken by both faculty and student members for accountability and future reference.

Weekly progress reports are provided to the supervisor. These updates help the supervisor maintain situational awareness, and just as importantly, they are a record of accomplishments for later technical reports, as well as updates from the Engineering Department to the Dean of the College. The headings for the progress report are "Progress made", "Difficulties encountered", and "Tasks to be completed next week".

Communication, professional etiquette, and other interactions in a business setting are emphasized during these processes to teach student workers the importance of understanding and working with other business professionals. Engineering Services is geared toward reflecting the engineering workplace in ways that would prepare the student workers for future careers.

C. Evaluating Student Worker Performance

All student workers at the College receive feedback on their work performance midsemester and at the end of the semester. Additionally, they receive a work grade. If student workers want to change workstations, they must receive a favorable recommendation from their current supervisor. This recommendation is often a deciding factor in whether the student is allowed to transfer workstations, and it was the deciding factor in choosing the current student worker.

Work traits assessed at midsemester and at the end of the semester are: reliability (25%), initiative/motivation (20%), responsibility/accountability (20%), quality of work (15%), teamwork/collaboration (10%), and communication (10%). The work grade is reported on the student's transcript. Additionally, the engineering department requires a work GPA of 3.0 in order for students to apply for an internship course.

IV. INITIAL PROJECTS

Engineering Services has taken on two external projects since its inception in Spring 2018. The first was converting a small room in a residence to be a music studio for a local family band, and the second project was improving the acoustic environment of the choir room in the Gittinger building on the College of the Ozarks campus. By design, the first project was limited in scope but revealed significant deficiencies in the modeling software and the test procedures. The lessons learned were applied to the second project, which was a more significant under-taking and revealed challenges of its own.

A. Petersen Studio

The project consisted of assisting a local bluegrass band to convert a small room in a residence into a practice studio. The room was approximately 9'x11' with 8' ceilings, laminate flooring, and gypsum drywall walls and ceiling. The goal was to reduce the reverberation (reverb), particularly at the mid and upper frequencies of the audible range, and cost was a significant constraint.

Figure 2. Petersen studio with absorber panels on wall and skyline diffusers on stools.

This project was limited to keep the cost and level of complexity low. The workstation did not charge for their services, and all improvements were installed for testing and demonstration then the room was restored to its original configuration. One of the objectives of the project was to get a grasp of how to use the measurement equipment and software, as well as step through developing and implementing a test plan.

During the project execution, the importance of test planning and documenting test procedures and execution was reinforced. Most significantly, the inadequacy of the free software chosen to model the acoustic environment became painfully apparent.

Despite the challenges encountered, the client was pleased with the acoustic modifications to the studio. The absorber panels and floor rug reduced the reverberation significantly. A picture of the studio with absorber panels and diffusers is shown in Figure 2. The absorber panels designed and constructed, and the skyline diffuser design using an online calculator [13]. The performance of these panels was characterized to be included in the software model of the room before installed in the room and tested. Diffusers require special facilities to characterize, which were not available. Their presence did not have a discernable effect on the acoustics of the studio.

Rockwool is high-density mineral fiber insulation, which has a noise reduction coefficient (NRC) of about 0.8 at 125 Hz and an average NRC of 1.0 across the audible frequencies [14]. The panel consists of 1"x2" furring strips, metal 'L' brackets, rockwool insulation, and a flannel sheet. The frame is 3 feet wide and 4 feet tall. There are two crossbars of furring strips that provide backing and support, each are 6 inches from the base or top. The rockwool is then inserted into the frame, two 1.5 feet by 4 feet slabs fit into one panel frame. The rockwool is then covered tightly with fabric. Flannel bedsheets were used for the demonstration panels; however, other more aesthetically-pleasing materials may be used. The covering is stapled tightly to the back of the frame to prevent sagging of the insulation over time. The total cost of each panel is $12, and construction takes one person around 50 minutes.

B. Gittinger Choir Room

The coordinator of the voice and music ministry programs at College of the Ozarks, Dr. John Cornish, approached the Engineering Department about improving the acoustic environment of the Gittinger Choir Room at the College.

The room had a constant hum at 125 Hz. The ambient sound pressure level (SPL) centered at 125 Hz averaged 65 decibels (dB) but reached 70 dB in certain locations. For comparison, normal conversation has an SPL of 60-70 dB [15]. The constant hum made choir practice difficult. Dr. Cornish also noted the E_4 note was especially "bright". Misunderstanding the meaning of this comment resulted in an important learning opportunity.

The room is 16 feet tall with a width of 41 feet and a depth of 20 feet. The front wall is angled slightly, which makes the depth of the choir room vary a few feet from front to back. The flooring is carpet tiles over concrete, the walls are ½ inch thick gypsum, and the ceiling is a dropped ceiling, two feet below a concrete roof. The room is half filled with metal risers for the choir to stand on and with two pianos. The total volume of the room is around 12,800 cubic feet. The College choir uses the room to practice, and it is used for voice and piano lessons.

An initial assessment of the facility determined a portion of the west wall was vibrating, which pointed to a mechanical cause of the 125 Hz hum. The College construction team was notified. They replaced an exhaust fan above the choir room, which significantly reduced the amplitude of the 125 Hz hum. This motor was located on the roof directly over a support column. The sound was traveling through the column and into the wall of the choir room.

The focus of the project then became reducing reverb times at and below the E_4 note, ~330 Hz. Reverberation times (RT) were measured using RT20 methods with the sound analyzer purchased with the WCC grant money. RT methods measure the time required for the amplitude of the sound diminish by the value of the number following RT, as measured in dB. The industry objective is the RT60 method; which means the time required for the sound to diminish by 60 dB, or 1/1000th its initial amplitude. However, this requires a sound source that is at least 75 dB above (5623 times) the ambient level of the room. As this is hard to achieve with limited equipment and in some cases, harmful to hearing, the RT20 method was used. RT20 measures the time for sound to decay 20 dB (1/10th the initial amplitude) and then interpolates that measurement to 60 dB of decay. To measure RT20 accurately, a test signal must be produced at least 35 dB above (56 times) the ambient noise of the room [16].

The user manual for the freeware used to model the Petersen studio was written in French, and the software was not user-friendly. An engineer on the engineering program's EAB, recommended Enhanced Acoustic Simulator for Engineers (EASE). EASE is an "acoustic simulation software for integrators, engineers and acoustical consultants" [17]. EASE is more robust and easier to use than the freeware and was used to model the RT60 values for the choir room.

The measured RT20 values were challenging to acquire, given they did not correlate with the data modeled in EASE as well as hoped, as shown in Figure 4. The differences above 500 Hz may be attributed to the measurements were taken in an empty room, and the model included an absorber field to represent the choir, as illustrated by the darker gray area of the model shown in Figure 5.

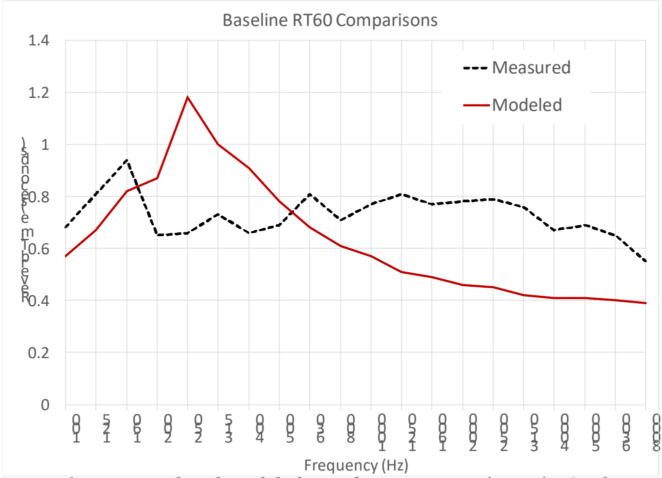

Figure 3. Measured and modeled reverberation time (RT60) of a choir room. The desired RT60 is 0.9-1.5 seconds across the audible range.

The simulation corroborated a "bright" frequency band near 250 Hz. Given the fidelity of the model, this likely corroborates the customer's complaint about the room's performance at the E_4 frequency. As a result, the goal became to reduce the reverberation at this frequency band by adding absorbers to the model.

The reverberation times were reduced; however, during the design review with the customer, he clarified that his objective was "liven" the room rather than "deaden" it. Further research revealed an industry standard for a choral room RT60 is 0.9 to 1.5 seconds, uniform across the audible frequencies [18]. The model shown in Figure 4 had times below 0.6 seconds. The presentation to the client resulted in redefining the problem and making a better effort to understand the scope of the project. This learning process emphasized the importance of properly defining the terminology, understanding what the client wants, and interpreting data correctly.

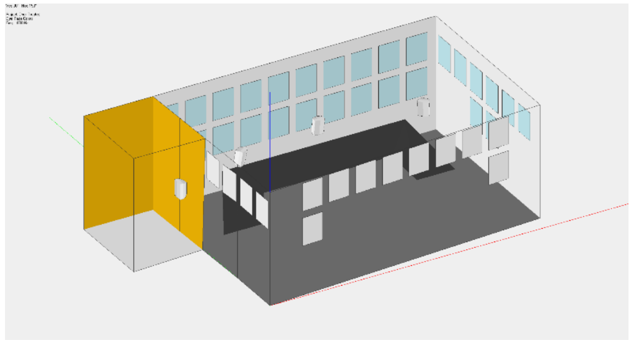

Figure 4. EASE Render of choir rehearsal room with absorber panels on walls. The front of the room is nearest the red line representing the x-axis.

With the problem properly defined, the student continued the engineering process by creating new designs that would enhance the room according to the data gathered in the last attempt. The new design included diffusers that reflect sound from nonplanar surfaces, such as pyramidal ceiling tiles. The diffusers increase the reverb time without resulting in echoes.

V. LESSONS LEARNED AND FUTURE PLANS

A. Lessons Learned

The learning experience of the first student worker are unlikely to be replicated. He independently learned two different acoustic software packages and how to use 3D computer-aided drawing software. Misunderstanding Dr. Cornish's desire to liven the Gittinger Choir Room, rather than suppress reverberation was due to the faculty's and student's lack of acoustics experience.

Both projects revealed deficits in technology and experience. However, there has been significant growth in those areas. Engineering Services designed and tested new products manufactured in-house to offer as solutions. Commercial acoustic software (EASE) was eventually purchased to replace freeware that was not as robust or user friendly. EASE appears to be performing well and the student worker's familiarity with the software was instrumental in being selected for an internship with an audio/visual design firm in the region.

B. Future Plans

The near-term plans include completing the Gittinger Choir Room project. Acquiring or fabricating ceiling diffusers then installing those diffusers should happen early in the next semester, which would complete step 6 in Figure 1. Acoustic characterization of the modifications, comparison to previous measurements and the simulated performance of the modifications will occur and be incorporated into the final report for the customer, completing the steps of the engineering design process in Figure 1.

Future opportunities to continue researching and implementing affordable remediation for acoustic environments are abundant. Other potential customers from the College and from the community have contacted the engineering department.

Before branching out into other technical areas, the process of knowledge transfer must be demonstrated. A sophomore student will join the workstation as the current student worker enters his senior year. Toward this end, a significant amount of effort has been spent documenting modeling and measurement processes. This documentation needs to be tested while the current student worker is still available to answer questions and refine the process based on personal experience.

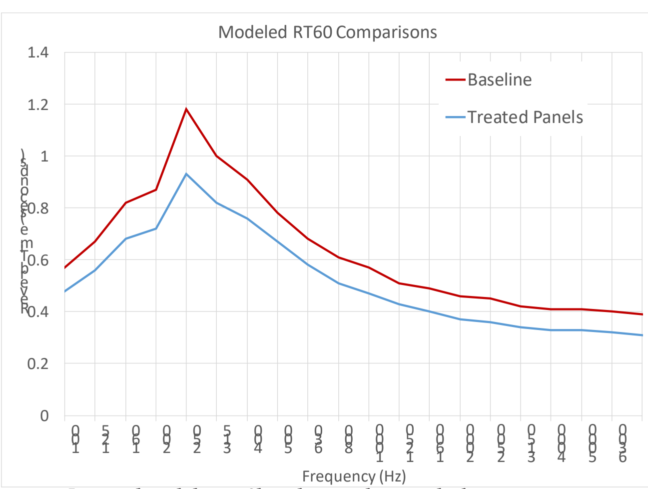

Figure 5. Simulated data of baseline and treated Choir Room

Ideally, one acoustic project per semester is planned to be accomplished once the workstation is fully functioning. As the engineering program grows, the community and College recognize the value of the services provided, and industry validates the benefits of the experience as they hire the student workers, other engineering disciplines are planned be added to the Engineering Services workstation.

VI. CONCLUSIONS

The Engineering Services workstation appears to be a valuable engineering and program management experience concurrent with the academic engineering program at College of the Ozarks. The faculty supervisor's inexperience in acoustics resulted in a learning experience of the first student worker that is unlikely to be replicated. Lessons learned in the first three semesters of the workstation promise a more refined exposure to acoustics engineering, though the variability of problems encountered and associated constraints will ensure future student workers will develop valuable engineering design skills.

Engineering Services provides a unique approach to teaching concepts of the engineering design process and developing professional skills. While the start of the workstation has been challenging, each effort made to improve adds to the value of this experience.

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PAPERS

Understanding the Nuremberg Trials: An Examination of the Use of Live Theatre as an Educational Tool

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Abstract— **This study examined what impact a live theatre performance has for university students. Does a play help college students contextualize academic content? Does a play offer benefits students do not gain from textbook readings and class discussions? Survey research conducted at Purdue University suggests exposure to a live performance offers benefits for college students in their ability to understand and critically analyze the historical events they learn within their coursework. Our research indicates live theatre could assist in enhancing traditional education models at the collegiate level and should be explored further as a potential methodology to aid in student success.**

Keywords—arts impact, theatre, arts benefits

I. INTRODUCTION

Education scholars maintain a strong and enduring interest in new measures to improve students' learning experience. Visualization techniques gradually gained popularity in the last decade in and outside classrooms because they tend to enhance attention, nourish interest, improve memory, and help integrate story plots into the learning process. Information conveyed by images, sounds, and videos are simpler to understand within a short timeframe, generating more engagement and motivation among students [1-2].

Learning activities in locations outside of the classroom, such as movie theaters and museums, could also result in an improved learning experience when carefully designed and organized. This is especially true with instruction in history. In the book Teaching History with Film, Marcus et al. [3] collected data in secondary schools to test the impact of using films to cultivate the students' historical literacy. The result shows that movies could help students learn about historical events and develop a sense of empathy.

Jay P. Greene and his team discovered that a visit to the Crystal Bridges Museum of American Art enhanced the students' knowledge, cultural consumption, tolerance, empathy, and critical thinking [4]. In a 2015 study using a rigorous experimental design, the researchers tested 670 students in grades 7 through 12 and found that live theatre has similar, and in some instances stronger, positive impacts than solely reading the textbook in improving knowledge of plot and vocabulary, level of tolerance, and ability to read other people's emotions [5]. Nevertheless, the team is concerned that the testing measurements included only state-provided math and reading tests (as well as the Reading the Mind in the Eyes test), and it encourages future researchers to develop new measures to collect and analyze educational outcomes [5].

Research on the potential positive impact of the arts in educational design continues to be a burgeoning line of inquiry. Like the aforementioned projects, research thus far has almost exclusively focused on students at the K-12 level. This leaves several unanswered questions. First, are these positive findings applicable to college students? Would research at the collegiate level support current theories? As Greene et al. pointed out, the field also suffers from a lack of alternative measurement tools beyond standardized math and reading tests [5]. While these tests are scientifically generated, nationally normed, and carry important weight in the academic success of students, they are not designed to answer some of our particular research questions. How do we assess the personal experience of students in addition to their knowledge about key moments in history or specific events? We are interested in what information we may miss when we simply ask students to take a standardized exam.

Our paper aims to fill in these gaps of knowledge about the impact of the arts through a pilot study using qualitative research methodologies. We build upon on the survey work of Glow and Johanson [6], aimed at understanding the intrinsic impact of performing arts attendance. They have found audience measurements of quality to include knowledge/information transfer or learning, managing risk, authenticity in performer interactions, and collective engagement. We solicited feedback from undergraduate college students about their experience watching a play in a theater. In the survey, we asked them to compare their learning experiences in a classroom, watching a movie, and seeing the play in the theater. Instead of simply providing a "yes-no" Likert-scale style of questioning, survey participants were asked to use short-answer fields to note the difference in their learning experiences and explain how and why they determined those differences. Upon completion of data analysis, surveys were analyzed to determine whether collegiate students gain valuable learning experiences as a result of attending a live performance. Based on the quality measurements of Glow and Johanson [6], their responses were organized into the following categories: previous knowledge, expectations compared to experience (risk management), live performance vs. other modes of learning, information gained, conveyed emotions, physical proximity, concentration and improved recall, empathy and critical thinking skills.

II. RESEARCH DESIGN AND MEASUREMENT

Our research was conducted during the winter of 2017 in Introduction to the Modern World (HIST 104), an undergraduate college history class at Purdue University in West Lafayette, Indiana. This course covers historical development of the West from the era of the Renaissance to the present day. The curriculum includes discussions about World War II and the Holocaust with aims to teach students how to think critically about historical events and evaluate them from their own perspectives. In consideration of course content covering the Nuremberg Trials held following WWII, we collaborated with the instructor of the course to offer her students an opportunity to attend a live theatre performance as part of a research project to investigate the potential impact of their attendance.

To participate in the research, HIST 104 students were recruited to attend a Purdue production of Judgment at Nuremberg, performed by L.A. Theatre Works and presented by Purdue Convocations, the performing arts presenter at Purdue University. The play commemorated the 75th anniversary of World War II. Judgement at Nuremberg dramatizes the trials of four German judges accused of crimes against humanity under the Nazi regime. Themes explored include the conflict between the rule of law and human rights, social justice struggles, international politics, and the pitting of ethics and personal responsibility versus public duty.

Notably, this production of Judgment at Nuremberg was delivered in the style of a live radio-theatre performance. Also known as audio theatre, radio theatre is, in its purest sense, a fully acoustic performance without many traditional theatrical components such as set design or transitional lighting, although this production did use period-appropriate costuming. It otherwise relied upon dialogue, music and sound effects to help the audience understand the story. This particular choice of performance style impacted the learning experience of students in a variety of ways as is discussed in the later analysis.

Students voluntarily participated and received up to 10 extra credit points on their total course grade for watching the performance of Judgment at Nuremberg and writing reports based on questions generated by the instructor. Although this mechanism has a self-selection bias, we do not observe any serious bias in our data pool based on the students' final grades. The students distribute evenly in each level of their grades, which means that students performing at a broad spectrum of academic levels, not only the highest- or lowest-performing students, attended the show. In addition, the primary aim of this study is to test a theoretical principle, not to make claims of generalizability beyond a collegiate audience [7].

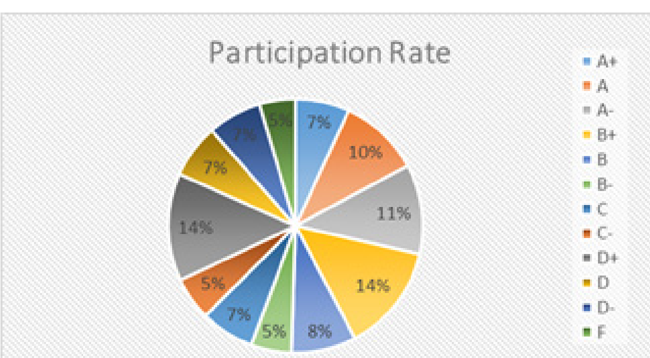

Figure 1. Study participation rates by final course grade

Out of a class of 84 students, 32 attended Judgment at Nuremberg and completed the extra credit report, which addressed the following topics:

1. Previous knowledge of the Nuremberg trials
2. Expectation of the play compared to their viewing experience
3. Differences in how they learned about the Nuremberg trials (classroom, live theatre, movie)
4. Most important takeaways after the performance
5. How would you describe the theatrical experience to a friend or family member?

Students were free to submit the report anytime between October 18 (the first evening of the performance) and December 12 (the end of semester). While four students submitted in mid- to late-November, most students turned in their report in early December, between December 6 and the deadline of December 12. Therefore, most students finished their reports around six to seven weeks after they experienced the performance. This may have influenced their memory in the sense that some minor details were lost as time elapsed. Although submitting a report this far removed from the time of performance was not ideal, their strongest memories would be those recalled after that passage of time.

Student extra-credit responses were in the form of Microsoft Word documents. After reading the full data set multiple times, we generated a series of codes or keywords. Initially using the work of Glow and Johanson.[6], we looked for themes they observed such as authenticity in performer interactions, which we coded as conveying emotions. One file was created for each code / keyword. The coding system was imported into the software NVivo, which supports qualitative and mixed-method research. This enabled us to better understand frequencies, investigate patterns, and visualize the complete data set.

III. RESULTS

A. *Previous knowledge of the Nuremberg trials*

Twenty-nine students out of 32 total, or 90.6% of the group, reported very limited knowledge about the Nuremberg Trials, as they had previously only read about the events in history textbooks during high school and briefly even then. Three students (9.375%) reported additional previous knowledge outside of what they learned in textbooks. Two students (6.25%) had viewed the 1961 film adaptation of the production, and one student learned about the Nuremberg Trials due to interest in the international legal system. Although that student arguably held the most previous knowledge, they noted that they missed many perspectives and misunderstood the significance of the trials.

This result is expected, given that the Nuremberg Trials are not heavily covered in high-school history courses. Because so few students reported prior knowledge of the Nuremberg Trials, we do not believe prior knowledge played a significant role in their perception of the live performance.

B. Expectations compared to viewing experience

As previously mentioned, this play was performed in the style of radio theatre. Most students expected a traditional, "Broadway"-style performance inclusive of the form's more traditional dancing, singing, and music. They also expected set changes. Four students (12.5%) were critical of the performance and thought it was less interesting than they expected. They also were critical of the actors' intentional use of heavy accents. In addition, two international students (6.25%) told us that it was difficult for them to understand the actors and storyline without the benefit of subtitles.

Although many students were surprised by the play's true performance style relative to their expectation, 24 students (75%) reported that the play exceeded their expectation. Three students (9.375%) commented that the radio-style drama helped them to concentrate because they felt curious about the style and setting. This result may encourage future researchers to be thoughtful about the choice of theatrical style they choose to present.

C. Increased information

Twenty-two students (68.75%) reported that the live performance presented more information than the textbook or in-class discussion. That information included but was not limited to:

- Background sound
- Voice of the actors
- Shake of the stage when the character walks
- Hidden stories of the German citizens, etc.

The stories offer the students valuable details so that they can immediately delve into the situation.

Among the students who mentioned the increased information presented in the live performance, thirteen (40.625%) of them believed that the live performance presented the story and emotions in a more direct, realistic way while still captivating them. Ten students (30.125%) expressed the feeling that the live performance offers "so much more" than a history class. Two students (6.25%) said the live performance does a better job portraying the actual courtroom than a film.

D. Conveying Emotions

An overwhelming proportion of students believed that the live performance conveyed stronger emotions or feelings than the textbook alone. Twenty-eight (87.5%) of the students said they could feel the emotional connection with the actors and therefore could continue to focus on learning more about the event. One student reported they found the live performance interesting because "I could see the emotions these people were going through at the trials that cannot be found in reading about the trials. This live performance was much more entertaining and easier to understand than reading a textbook." Fourteen (43.75%) of the students felt that they were "personally engaged/ involved" in the performance. Five (15.625%) students said they never considered that historical figures could have such strong, passionate emotions because the textbook often fails to mention that type of information. One student noted: "The performance was different because it was far more engaging. There is a definite advantage over other modes of learning because this creates an emotional response to go along with the knowledge you gain."

Figure 2. Scene from the play Judgment at Nuremberg

Eighteen (56.25%) of the students agreed that, compared to reading a textbook, live theatre is a much more personal experience and gave them "a person to empathize with rather than just a name in a book." Additionally, six (18.75%) of the students said they felt connected because of the intense, engaging atmosphere cultivated by live theatre. They felt that it is more impressive than a film because they witnessed real people acting live and on stage. The students were easily able to imagine the actors were the real historical figures at the trial. Two students (6.25%, not those who watched the film) thought that a film could neither convey characters' emotions nor elicit an audience's feelings as well as a live performance.

E. Physical Closeness

Sitting in front of the real actors, twenty (62.5%) of the students reported feeling as though they were physically present in the courtroom. One student stated, "I can feel that the actor is breathing next to me."

This perceived proximity forced them to be more involved, as they feel a "physical" connection to the event. Among them, twenty-six (81.25%) of the students felt like

Figure 3. Scene including historic footage from the play Judgment at Nuremberg

they "went back to the era and to that place," were one of the decision-makers in the room, and listened carefully to the testimony of the characters. In doing this, students may have experienced the struggle of the judge, which made them think deeply about the meaning of the Nuremberg Trials. To some students, it is "no longer just a historical event in the textbook, but something happened to real people."

Six students (18.75%) compared the live performance to viewing a film and said that films did not elicit a physical connection. They also made emotional connections with the characters by watching a historical drama film but not as strong as in a live performance.

F. Concentration & Improved Memory

Six students (18.75%) used the term "concentration," or the similar terms of "focus" and "attention," when comparing the live performance to watching the film. They reported having a higher level of concentration at the live performance. According to a student, the live performance "forces you to accept that it has happened and you are not killing time watching an irrelevant play."

Four students (12.5%) noted that because they did not know the actors, they were forced to concentrate on the historical event itself. One student complained that the drama forced them to concentrate on the plot because of the intensity of the live performance. They reported an inability to relax during the performance. Nonetheless, the student believed the live performance was a more effective learning tool than watching the film.

Twenty-six students (81.25%) believed that the live performance helped them retain information about the Nuremberg Trials more efficiently than the film or the textbook. Because the students believed the live performance brought more information, direct emotion, and a closer physical connection between the audience and the material, it may have made it easier to comprehend. The performance also helped students understand myriad issues surrounding the Nuremberg Trials, including the background of WWII, the establishment of the international legal system, and the life of everyday German citizens and the pressures placed upon them. Results suggest the richness and depth of information presented in the live performance resonated with the students for a longer time period and left a larger impression. As one of the students wrote, the event is "alive" when they remember it: "When think back, it is alive, not texts."

G. Word cloud

The figure that follows is a word cloud poster produced by the software system NVivo. This is a query made based on word frequency pulled from the descriptions students used when discussing the difference between learning from the live performance versus the film or textbook. It is a straightforward visual depiction, with the largest words being the ones used most often by students, and shows that personal feelings are significant when seeing the live performance. The students reported the live performance felt "real" and caused them to think more about the characters (i.e., the officials, the judge, etc.) in the Nuremberg Trials. Students also discussed the difficult ethical questions posed

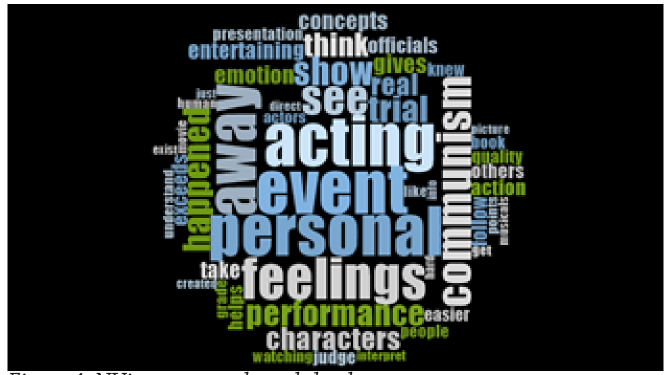

Figure 4. NVivo generated word cloud poster

in the live performance.

H. Empathy & Critical Thinking Skills

Empathy development is another factor of interest when understanding the potential impact of live theatre. In previous studies, scholars have found that watching a drama would increase the students' empathy for others [4-5]. In our study, every student mentioned that the live performance offered a "different / another / new perspective" through which to look at the world. All students expressed complex feelings toward the German characters in the Nuremberg Trials. Fourteen students (43.75%) reported feeling the struggle of the judge as he was making some "really hard choices." Twenty-eight (87.5%) of the students said that prior to watching the live performance, they never thought about the living conditions of the German people during and after WWII nor did they realize that these German citizens were real people with hearts and feelings. Following exposure to the live performance, their impression of the people during this historical period appears to have gained nuance. They learned that "just because someone is from a certain place does not necessarily mean that they support everything that happened there." Their view on the Nuremberg Trials was "no longer black and white."

Many students also showed signs of improved critical thinking. Justice can be complicated, and students came to the understanding that a normal person can be just a few small steps away from making poor ethical decisions. Results suggest the performance caused them to reconsider their understanding of complex moral dilemmas. Twelve (37.5%) of the students discussed the German characters who assisted the events of the Holocaust during WWII and the ethical conflict they felt watching the show. One student noted: "I gained a perspective of how the effect of World War 2 (sic) was like for the Germans. I categorized them as all being bad, but that is not the case." Students gained an understanding of the difficult task the judge faced during the Nuremberg Trials and how that might relate to our current judicial system. A student said: "I think the trials make us all wonder what we could do in the position of the judge." Another student stated: "It was very solemn, and make (sic) me think about what actually happened in this world, and what could happen still." Last and perhaps most compelling: "I learned about how tough it was to assign verdicts to bystanders in Germany post World War 2 (sic), and how this moral quandary still exists in today's judiciary system."

IV. LIMITATONS AND DISCUSSION

Our research suggests that live theatre could have a positive academic influence on students at the collegiate level as a tool to learn about historical events. We are nevertheless clearly aware of limitations in our study. The most serious issue is with the representativeness of our sample. Because we chose, for our participation pool, a currently active history class made up of students with either an interest in history and / or mandatory requirement to attend, our sample was not randomly selected. We could not control who selected the class, who went to the performance, or who would eventually finish the report. In addition, we cannot refer to our research as "robust" with only 32 participants. This limits our ability to make broad claims beyond that of our own population at Purdue University. However, even with those limitations, the evenly distributed sample among the GPAs indicated a balanced distribution of participants within the class.

This research was intended to serve as a pilot study in the field. We hope our research findings will encourage other scholars to develop more robust studies at the collegiate level. Our study suggests that students tend to better remember and understand a historic event when exposed to its story via live performance – particularly live theatre. Live performance has the potential to improve skills in critical thinking and offers an opportunity to analyze an event from multiple perspectives. Our research could serve as a stepping stone for cross-disciplinary studies between live theatre and education methodology research, and future studies could extend our findings. For example, additional research could further examine the ability of live theatre to address and teach ethics and morality and expand on current research related to improvements in empathy skills. Future studies could examine differences between various types of live performances. For example: Does a musical have a larger impact than a radio-theatre performance?

As most of the research aimed at understanding the impacts of a live performance is still in its infancy, we believe even small studies such as this one contain merit. Although our research certainly suggests live performances can have a lasting academic impact on college students, much remains to be learned. We plan to continue to understand what students gain as a result of their exposure to the arts and hope that other researchers continue these lines of inquiry as well.

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Using Storytelling and Robot Theater to Develop Computational Thinking

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Abstract—**The University of Iowa's Robot Theater Project teaches computational thinking and promotes STEM education in the context of the performing arts. Students write scripts and program robots to give live performances on stage; over the past 5 years we have taught 122 students to program robots, and our robots have performed in front of several thousand students, teachers, and parents. In this experience report, we introduce the project, describe the framework used to coordinate the behavior of multiple robots in a scene, and discuss the challenges with live performances involving robot actors from different manufacturers. We also describe an initiative to develop performances that explore human experiences and behavior, where the content of these performances centers on material related to diversity andrepresentation.**

I. INTRODUCTION

The University of Iowa's Robot Theater Program (UIRTP) promotes STEM (Science, Technology, Engineering, and Mathematics) education by teaching students to program robots to perform theatrical skits in front of live audiences. Our program incorporates the language and performing arts into the STEM curricular framework, inserting the arts into STEM and expanding the acronym to STEAM. In addition, our program embraces the idea that computational thinking should not be limited to courses that are part of the typical STEM curriculum[1].

Algorithmic thinking, decomposition, abstraction, and pat- tern recognition are just a few examples of computational thinking skills that are used across disciplines. Incorporating computational thinking into social science, writing, and performing arts classes imparts digital skills and competencies to students who may avoid enrolling in traditional STEM-related classes. Our idea was to develop an innovative "hook" to generate student interest in STEM subject matter, making computer science education more accessible to diverse learners.

In our program, students learn to program twocommercially available brands of robots, NAO humanoid robots and Cozmo robots, to tell stories and act in theatrical skits. Ourgoals for students include learning algorithmic thinking, advancing problem-solving skills, developing a passion for storytelling, gaining technical expertise, and fostering an appreciation of the relationship between creativity and STEM fields. We have offered first-year seminars as well as computer science special topics classes in Robot Theater. In these classes, students write scripts and program robots to perform theatrical skits on stage. In past semesters, students have written skits related to bullying, political debate, and the ethics framework that is embedded into the laws of robotics. We have observed that the students' scripts often focus on exploring human values through the eyes ofrobots.

The UIRTP also includes STEAM outreach programs for underrepresented K12 students; our target populations include female students, students in rural communities, and students from low-income families. Our STEAM outreach activities involve hands-on workshops where students develop computa- tional thinking skills while learning to program robots [2]. At the end of each workshop, the robots perform skits developed during the workshop; the students are eager to show their parents what they learned, and to share what they have learned about the robots during post-performance QA sessions.

We continue to showcase participants' creative projects. We network with teachers to deliver robot theater performances at schools across Iowa throughout the school year. These performances consist primarily of skits that were developed by students in our classes and workshops. Showing students what their peers have created helps us dispel the misconception that programming robots is beyond their capability.

II. BACKGROUND

A. *Motivation*

According to the National Center for Education Statistics, there were fewer Bachelor's degrees in computer and informa- tion Sciences conferred in 2015 - 2016 than those in either the visual and performing arts or social sciences and history: there were 1,419 Bachelor's Degrees in computer and information science awarded, compared to 1,456 Bachelor's Degrees in visual and performing arts and 2,520 in social science and history[3]. When comparing college majors considered to provide career training and professional opportunities, we note that business and the health professions still dominate: there were 5,201 degrees in business and 5,040 degrees in the health professions, yet only 3,416 degrees in computer science con- ferred. One reason students don't major in computer science is themisconceptionthatcomputerscienceislimitedtocomputer programming[4].

Research suggests that by incorporating computing components into unexpected and non-traditional activities, wecan pique interest in technology and broaden participation in computer science [5]. Consider that studies in the area of gender differences in post-secondary education and career choice suggest that young girls have wide and varying interests. However, beginning in middle school, girls' interest in STEM fields drops, with women being underrepresented

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in post-secondary technology-related majors and careers [6]. Ad- justing the curriculum, pedagogy, and culture of the profession to be more accessible and encouraging to diverse learners is a critical step in closing this gender gap[7].

B. Pedagogy

Interactive learning is central to UIRTP, as students engage in a combination of individual and collaborative activities. Studies show that student performance improves when goal interdependence and resource interdependence are incorpo- rated into a pedagogical framework. In addition, positive inter- dependence fosters the development of cooperative attitudes and helps to generate greater academic and personal social support.[8]. Students typically work individually to draft the scripts for their scene, and then collaborate with their peers in refining their scripts, programming the robots, and working out the stage design and performance components for the live show. Students often work individually to learn about a particular capability of a robot and then share their expertise with their peers. Every student contributes to the final show, so the success of individuals is linked to the success of the group: students are motivated to help one another and share resources and information so that the final show is a success.

C. Storytelling and Computational Thinking

Stories transcend generations; they are used to document history and foster a sense of community. They are a source of entertainment and inspiration, and can play an important role in the learning process. People are able to create stories and later share them via a variety of traditional formats includ- ing text, audio, and video. Furthermore, recent technological developments in photography/videography, editing software, and content hosting platforms have significantly impacted the process by which stories are constructed and shared.

Storytelling is fundamental to the human experience and can be a powerful teaching and learning tool. Throughout human history, storytellers have shared knowledge and in- formation; stories are a way for us to make sense of our world. Storytelling involves bringing stories to life and sharing these creative works. A well-told story is immersive, engages our imagination, triggers an emotional response, and piques our curiosity. Stories are also very personal, and connect the storyteller to their audience. By using storytelling as the center of our project we encourage students to tell stories that are based on their interests and experiences, empower them with the ability to use technology to enhance their stories, and enable them to determine the manner in which their stories are told as well as how they are shared.

Computational thinking skills can be applied to the process of storytelling in a variety of ways. For example, a storyteller decomposes a story into a coherent sequence of events. As another example, the pattern for stories in the Hero’s Journey genre includes the development of three components: the departure, the initiation, and the return. Linking computational thinking to the art of storytelling can help students gain an appreciation of the relationship between creativity and STEM fields.

We are using storytelling with robots as a way to encourage girls with high math and verbal abilities to engage in a computer science curriculum. The storytelling potential of the robots is compelling; this observation is supported by other researcherswhoareincorporatingrobotsintotheater[9]. There are a variety of groups exploring the use of robots in the per- forming arts. The Portland Cyber Theater is led by Marek A. Perkowski, a self-described robotic puppetteer and Professor of Electrical Engineering at Portland State University. In2015, The Brooklyn Academy of Music orchestrated a 15-piece dance ensemble which was comprised of eight humans and seven NAO robots[10]. The 9th annual Robot Film Festival, which celebrates robots on screen and in performance, will be held in Los Angeles, CA in August, 2019[11]. Videos of robot performances can also be readily found on YouTube.

III. TECHNOLOGY

Incorporating emerging hardware into an educationalframe- work is not without challenge and risk, because the tech- nology landscape is continually changing. Products are often discontinued; sometimes, but not always, companies offer new and more sophisticated replacements. Companies can change their business model, be acquired or go out of business completely. After an acquisition, a company may choose to stop manufacturing or supporting certain products. There are other factors, like changes in import regulations, that may impacttheimplementationofanewlydevelopedcurriculum.

A. Hardware

In the UIRTP we intentionally focus on programming robots to perform on stage rather than on designing and constructing robots that can be used as actors. We rely on manufacturers to develop and support the robots that we use, which means that we also are affected by the corporate stability of the developers. We primarily use two types of commercially available robots in our performances: NAO humanoid robots, currently being developed by Softbank Robotics, and Cozmo, which is developed by Anki.

NAO ROBOTS: The NAO robot is a programmable, 57 cm tall humanoid robot. Each NAO robot has two cameras, four microphones, nine tactile sensors, and eight pressure sen- sors. Their communication devices include a voicesynthesizer, LED lights, and two high-fidelity speakers [12]. While these robots are primarily programmed using Choregraphe, which is a proprietary visual software environment, there are also Software Development Kits (SDKs) that enable them to be programmed in Python, Java, C#, F#, VB, and C++. Each NAO robot costs about $9000.

NAO robots were originally developed by Aldebaran Robotics, which was acquired by Softbank Robotics. When our program was initiated, we purchased five new H25 NAO robots. We acquired an additional H25 NAO through E-Bay at a reduced price, and then purchased an upgraded V5 model. Fortunately, the firmware and software environments for these two older models are the same, and we are able to use these two models interchangeably during a performance. We recently added two NAO V6 robots to our troupe. Shortly after placing our order there were changes in U.S. import regulations, and the uncertainty around new tariffs being imposed resulted in a four month delay in delivery.

Robotics technology is changing rapidly, and the evolution of the NAO robots has affected our work in a variety of ways. The release of the NAO V6 was accompanied by a new version of Choregraphe (2.8), which is not backwards compatible with the older NAO models. While programs cre- ated using earlier versions of Choregraphe can be opened and run in Choregraphe 2.8, programs written in Choregraphe 2.8 cannot be opened in older versions of Choregraph. Creating performances that use both the older and the newer NAO models will now introduce programming and compatibility challenges. Of course, our performances will benefit from the improvements in the hardware and software for the new model. There are more aspects of speech, such as pauses, emphasis, and intonation, that can be specified in the V6 model. This enhanced control over diction will certainly improve our theatricalperformances,butnotallofourrobotswillbeableto take advantage of these refinements, adding yet another layer of complexity to production planning and casting.

COZMO ROBOTS: Cozmo is a palm-sized robot that drives on treads and is equipped with a tiltable head and moveable lift arm that can be used to pick up and carry small objects. Cozmo has a speaker and a small LCD panel display screen that, in conjunction with sound effects, can be used to mimic human emotional responses. It has a built-in camera, Bluetooth connectivity, and an infrared light and sensor that can be used to detect objects[13]. Cozmo comes with three cubes that it can interact with once connected via Bluetooth. Cozmo requires a mobile device to operate; it can work with an inexpensive Kindle Fire Tablet, a smart phone, or an iPad. Cozmo can be programmed in Scratch through a mobile app, or it can be programmed on a computer using Python through an SDK. There is a strong developer community, and a forum where people can share ideas and ask questions. There are resources on Thingiverse for 3D printing props for Cozmo to use in theatrical skits. The retail price for Cozmo is $180. The relative affordability of Cozmo, combined with the ability to program in both Scratch and Python, makes it ideal to incorporate into curriculum across K12 as well as the post-secondary level.

A recent development in Anki's corporate structure created a significant challenge to our program. In April, 2019, Anki announced that they ceased product development and are no longer manufacturing robots. In their announcement, they indicated that they would be taking steps to ensure that the developer tools for Cozmo would continue to be available. Uncertainty in the future availability of the robots and their continued functionality forces us to be nimble; we are con- stantly looking for new robots to bring into the UIRTP and are prepared to incorporate new technology as it develops.

B. Software Environments

NAO and Cozmo each have their own individual pro- gramming environments: NAO robots can be programmed in Choregraphe, and Cozmo robots can be programmed in Scratch through Cozmo's mobile app. We chose to use these two types of robots because they can both also beprogrammed in Python, through their respective SDKs. The Python versions required for each of the robots is different, however. The SDK for NAO uses Python 2.7, whereas the SDK for Cozmo uses Python 3.5.1 orlater.

The different versions of Python can present a variety of challenges when incorporating other technologies into our performances. For example, the Leap Motion sensor is a device that supports hand and finger movements as input. The Leap Motion Python API supports Python 2.7, which means that using the Leap Motion with the NAO robots is fairly straightforward. Unfortunately, using it with Cozmo required abitmoreefforttoconfigure,butitcanbedone.

We have configured a network to facilitate communication between robots (discussed in more detail in Section V-A). Briefly,WehaveaRaspberryPirunningachatservice,andthe robots use the Python socket library to send data through the chat service. The differences between Python 2 and 3 create minor issues with sending messages across our chat server. In Python 2, the implicit str type is ASCII, but in Python 3 the implicit str type is Unicode. In Python 3, messages sent by Cozmo over our network need to be sent as raw byte strings, and will be received and parsed as such. We use the socket library function sendall() to send messages: in Python 2, we would use sendall("Hello"), but in Python 3, we need to use sendall(b"Hello"). This slight difference in syntax is easy for new programmers to miss, and these types of errors often stop a scene from progressing during our debugging rehearsals.

C. Hardware and SoftwareUpdates

Firmware and app software updates can wreak havoc on our performances, workshops, and demonstrations. In the past, Anki issued relatively frequent updates to the entire Cozmo ecosystem, including the robot, the mobile app and the SDK. These updates did not always occur at a convenient time (e.g. right before a performance or in the middle of a workshop), and often installing the updates was required in order to continue to work with Cozmo. Sometimes an update to theapp would create a mismatch between Cozmo and the SDK, which then meant that students would have to download and install the corresponding new version of the SDK before they could run their programs on Cozmo. Now that Anki has shut down, future updates are not expected, so this is unlikely to be a problem going forward.

Updates to the NAO robots can be accomplished through Choregraphe, but now that the V6 model has been released, future updates to the previous models are not expected, and support for those models may eventually be limited. Because the V6 model is relatively new, the firmware updates to those models happens more frequently than with the older models. The changes also seem to be important, as kinks in the new ecosystem are being worked out. So, keeping up with those updates can be a time-consuming, and necessary, endeavor.

An advantages of using NAO and Cozmo robots is the strength of the developer community. The forums and other resources available help solve technical problems and share lessons learned. The makerspaces associated with each type of robot are also a valuable resource for making props for our skits. In fact, these extensive resources are an incentive to continue to use the older models, as resources for new models can take time todevelop.

IV. UI ROBOT THEATERPROJECT

A. Inspiration and Evolution

The UIRTP developed out of a proposal to develop a class to make algorithmic thinking concrete via collaboration with the performing arts. In the initial offering of this project-based class, students from computer science, electrical engineering, and dance collaborated to choreograph dances and program NAO humanoid robots to deliver a dance recital. In this class, performing arts students learned about computation and the technical aspects of computer programming, while the STEM- minded undergraduate students developed a more detailed understanding of the creative process, choreography of dance, andthemechanicsofhowthehumanbodymoves. Allstudents learned how to work respectfully as a team and with people who bring varied strengths to the table. Because students inthe class were working directly with robots, conversations about the impact of robots on our society developed organically.

Subsequent offerings of classes combining robots and the performing arts attracted students with an interest in theater and storytelling. Students were inspired to write original content for the robots to perform, and to act alongside them on the stage. Students often embedded current events into their scripts. During the 2016 political campaign, for example, students wrote a scene where robots running for political office debated issues related to the integration of robots into human society and robot discrimination. Students were able to include some of their specific concerns regarding robotics technology into their script, such as the impact of automation on employment. Historical events have also inspired students to develop an interesting range of skits. A celebration of the 400th anniversary of William Shakespeare's death inspired students to program the robots to perform an abridged version of Romeo and Juliet.

The scripts that the students write for the robots to perform have evolved dramatically since the beginning of the program. At the start of the program, students only had access to NAO humanoid robots, and they initially programmed the robots to perform renditions of familiar scenes from TV shows, movies, and comedy routines. Then they started to explore relationships between robots, and to write original content for the robots to deliver. For example, one group of students wrote a scene where the robots attended summer camp, and were sitting around a campfire telling scary stories. Next, the students started to explore relationships and interactions between robots and humans. One student wrote a play that involved having a human explain spirituality and prayer to a robot.

Once we incorporated Cozmo into the UIRTP project, students began to use the different types of robots to reflect aspects of human behavior related to diversity and inclusion into their productions; they started to explore relationships between different types of robots, and wrote skits related to bullying and exploitation. Expanding the types ofrobot actors available to the students in the UIRTP has affected the complexity of the scripts that the students are inspired to write. Robot diversity has certainly had a positive impact on the UIRTP.

B. StudentsReached

A total of 122 students have participated directly in the UIRTP since our first class in Spring 2014. Seventeen undergraduate students have taken a class in Robot Theater/ Dance, and 22 students have taken a first-year seminar in Robot Theater. We have had 41 middle-school students (41% female) enroll in the Robot Theater summer classes offered through the Belin-Blank JSI (Junior Scholars Institute) program, and 12 girls enrolled in the pilot offering of the Robot Theater summer class offered through the Belin-Blank BLAST program. An additional 30 elementary-school students have learned to program robots during weekend workshops offered through the Belin-Blank WINGS program. It is important to note that the number of NAO robots available for our classes and workshops necessarily limits the number of students that can enroll each time it isoffered.

As part of our outreach program, student-created skits are shown to hundreds of K12 students around Iowa each year. The robots perform at school assemblies and STEM-related events. The robots also perform at STEM events held on the University of Iowa's campus. Overall, we estimate that several thousand parents, teachers and students have been introduced to the idea of robots in theater and have watched our robots perform.

V. ROBOTS AS ACTORS: LESSONSLEARNED

There are several misconceptions regarding *robotic behavior*. One is that a robot will run a program in exactly the same way consistently. Another is that robots of the same model are interchangeable. Students who work with robots in our project learn very quickly that NAO robots have unique characteristics, in part because of their internal calibration and their use experience. This is especially true regarding movement. For example, some of our robots are better dancers than others, and some are better at walking in a straight line than others. Students discover the quirks associated with a particular robot, learn to think of the robots as distinct actors, and develop a robot-casting process as they create their scenes.

A. Communication inPerformances

In order to have multiple robots perform on stage, it was necessary to develop a way for the robots to communicate witheachother.Forscenesinvolvingonlyrobotactors,we take advantage of the network capabilities of the robots. We use a router along with a Raspberry Pi running a Python chat server to facilitate inter-robot communication. With this chat server, any device in the chat room can send a message, and every message is sent to every device in the chat room (other than the sender). At the start of a scene involving multiple robots, each robot is programmed to join the chat server and start listening for messages. The content of these messages can be as simple or complex as we decide; for the most part, we keep the messages simple by only including information on which robot should speak, and which line in the scene to deliver. A robot parses each message to determine if it should speak, delivers its lines, and then sends amessage to the chat server to move the scene along. This process also allows us to trigger multiple robots by the same message, enabling complex synchronous behavior in a scene. We are able to use similar Python code to control communication for both NAO and Cozmo robots.

Our performances are highly dependent on the robots being connected to the network, listening for messages, parsing the messages correctly, and sending the correct message after a line is delivered. Rehearsals typically involve identifyingstring comparison errors and fixing typographical errors. While it may be useful to have the NAO robots stream video fromtheir cameras, this can put a strain on the network; the robots will sometimes miss messages or drop their network connection completely. If this happens during a performance, it can be challenging to re-establish the network connection and continue the scene where the actors left off.

Some performances involve combining multiple robots and human actors on the stage. NAO robots have speech recognition capability, which we have used in theatrical skits with limited success: on the stage, the robots pick up ambient sounds and are unable to reliably hear their cues. This can result in the robots speaking too soon or stalling the performance. We do use this approach in scenes that involve humans and robots together. The human actors have to be prepared to improvise to keep the performance moving if the robots do not hear their cues, and to adjust their delivery if a robot starts speaking its lines early. While this does present some challenges, it also creates performances that are unique and dynamic.

B. *Movement on theStage*

In addition to the challenges involved in using different robots and different models, implementing programs involving movement and action may not go as planned. Stage blocking for a scene can be robot-specific for both NAO and Cozmo robots. Each NAO robot has its own internal calibration and gait, so an instruction to move a certain distance does not always yield consistent results across robots, even if they are the same model. For Cozmo, incorporating certain behaviors into a scene (such as picking up a block) can introduce uncertainty with Cozmo even being able to complete a task, and could stall the performance. In addition, a robot's battery level can affect its internal calibration and navigation, making it important to be aware of battery levels for all of the robots during a performance.

Issues related to movement are not limited to the manner in which the robots move; the characteristics of the stage floor can have a dramatic impact on a robot's mobility. Cozmo moves using treads, and while it can move on a variety of surfaces, we must include the type of surface when specifying the distance and speed that Cozmo should move. It moves faster and go further on a smooth surface, like tile or wood, than it does on carpet. The NAO robots must work to maintain their balance when they walk, and so the surface of the stage can be a significant limitation. We prefer a relatively uniform and slightly textured surface, like wood, for NAO robot performances.

Hardware differences between the NAO and Cozmo robots present a variety of challenges in staging scenes involving both types of robots. Cozmo is considerably smaller than the NAOrobots, making it more difficult for the audience to see. The maximum volume from Cozmos speakers is noticeably lower than that of the NAO robots, making it more difficult for the audience to hear. The character length of the lines that we can program Cozmo to deliver are limited by the size of Cozmo's memory; we do not typically run into such limitations with performances using NAO robots.

VI. FUTURE WORK: DIVERSITY INITIATIVE

For this initiative, we are developing a series of short skits that focus on exploring human experiences and behavior using robots as actors, where the content of these performances centers on material related to diversity and representation. In addition, We would like to use robot theater to provide a voice to people who might not otherwise be comfortable or able to present their stories personally. We will examine questions related to how characteristics of an actor impact the the way that an audience member connects with the content of a story. We intend to develop a process for people to submit their storiesfortherobotstotellusingsocialmediaavenues,andwe will live-stream these performances using available streaming services.Theskitswillbeaddedtoourperformancerepertoire, and video recordings will be posted on the UIRTP YouTube channel. We will monitor interest in this storytelling enterprise through subscriptions andviews.

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International competition as stopgap curriculum: Case study of Ryerson Invitational Thrill Design Competition

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Abstract— **Students aspiring to careers in the themed entertainment and attractions industry have few formal options to learn and demonstrate skills and knowledge specific to the industry. Students have shown initiative in developing extracurricular activities, and industry has reached out to offer "next generation" programs and internships. It still remains problematic for industry employers to select the best qualified students from a large pool of aspirants and for motivated candidates to stand out as highly qualified for these opportunities. The Ryerson Invitational Thrill Design Competition (RITDC) was developed to address this problem. RITDC provides learning experiences and performance evaluation with not only completion as an indicator of accomplishment, but concurrent interactive evaluation by judges from industry. As such, although the competition is formally an extracurricular activity, it functions as stopgap curriculum. This paper describes the origin and evolution of the competition and the challenges it has encountered, and the response from participants and industry.**

Keywords—themed entertainment, attractions, student design competition, internship

I. INTRODUCTION

Amusement attractions comprise an important component of the global tourism economy, enabling individuals, families, and groups of companions to experience immersive and interactive entertainment. The International Association of Themed Parks and Attractions (IAAPA) reported an estimated $44.8 billion in global spending at theme parks in 2017 [1]. The top 10 theme park groups worldwide had an estimated 8.6% growth in attendance in 2017 [2]. The 25 largest parks had an estimated 4.7% attendance increase in 2017 over 2016, with over 242 million visits. Several regions are notable hubs for theme parks, and TEA/AECOM (2018) reported over 75 million visits in 2017 at just the largest six attractions in Florida. Florida operations of Walt Disney Parks and Resorts, including its supply chain, have been described as contributing $18.2 billion, or 2.5% of the GDP of the state of Florida [3], and likely account for Orlando's rank as the leading tourism destination in the USA [4]. However, theme parks are found all over the world.

The themed attractions economy comprises not just revenues, expenses, and employment of park operations, but also attraction design, manufacture, construction, and installation of attraction components. Major attractions integrate systems from multiple manufacturers sourced from around the world. For instance, the northern climate would seemingly limit the industry presence in Canada to seasonal operation of outdoor amusement parks and carnivals, but several major Canadian firms contribute prominently to the design and manufacture of waterslides and waterpark equipment (WhiteWater West, Proslide Technology), media-based attractions (Dynamic Attractions, CAVU Designwerks), and master planning and creative services (FORREC), among other components. The annual conferences of IAAPA showcase products and services from over 1,000 manufacturers and suppliers [5]. An industry rule of thumb is that park development budgets exceed $100 per first-year guest [6] [7]. A single attraction may cost tens of millions of dollars to develop [8] (p. 319-320) with major multi-attraction developments reaching into hundreds of millions of dollars [9][10]. Notable multi-year redevelopments have reportedly exceeded $1 billion [11] [12] [13], and major theme parks may maintain annual investment in redevelopment of $500 million to maintain leadership positions in the industry [14].

Amusement attractions are engineered processes that are unique in that the product they manufacture is a compelling human experience, such as "fun", "wonder", or "thrill". Attractions involve ride and show elements. Both involve engineering from various disciplines: mechanical, electrical, computing, industrial, civil and chemical engineering, as well as human factors, biomedical, and systems safety engineering. Engineers collaborate with other design disciplines such as architectural science, interior design, fashion, and theatrical specialties, to create attractions that meet strategic business needs.

The industry is a "dream job" for many young people, which generates a large candidate pool. Employers commonly use academic performance as a screening criterion [15]. Academic performance such as grade point average (GPA) is a readily available measure and has some relationship to cognitive skills and relevant knowledge, but the association to work performance is unclear [16] and it may not be the strongest predictor [15], and related experience is a higher priority for employers [17]. In addition, some firms or hiring managers recognize that GPA may exclude candidates with knowledge and skills to produce work performance [18] [19]. "Job tryout" performance is a stronger predictor of work performance [15] [20]. Job tryouts also provide a preview of the nature of the work. A body of literature on "realistic job previews" has emerged to counter turnover resulting from disillusionment and unmet expectations about the nature of the work [21]. Unrealistic expectations can be a risk if candidates' career interests are based on childhood dreams or enthusiastic guest or "fan" experience rather than realistic job knowledge.

Internships enable a candidate to learn practical skills and provide an opportunity for the employer to evaluate a candidate for later employment [22]. They provide hands-on experience that makes candidates more competitive on the entry-level job market [23] [17]. Internships can benefit the student's academic training as well, since subsequent course selections can be informed by industry mentors. Internships of predetermined duration also eliminate a disadvantage of job tryouts, that supervisors may be reluctant to terminate marginal performers [20]. For these reasons, students are keenly interested in qualifying for internship or co-op positions. Whereas unpaid internships have been a subject of controversy [25] [26], attractions industry internships are typically paid. This may not be entirely altruistic, as paid interns clearly produce work for hire, thus the intellectual property belongs to the employer.

While the availability of attractions industry internships is fortunate, the importance of internships increases the pressure to secure them and shifts the intense competition earlier in the educational timeline. While employers are unlikely to entirely disregard general academic performance in screening internship candidates, a balanced assessment will include the candidate's industry **knowledge and skills** related to the position and **evidence of performance ability**, in addition to the candidate's **motivation and passion** for the industry.

II. STATUS QUO

Students have used several strategies to distinguish themselves as internship candidates for attractions industry employers: an industry-specific program of academic study, industry oriented extracurricular activities, and participation in industry educational experiences. These options will be briefly discussed in the next sections in relation to the evidence they provide for employers.

A. Formal educational options

Industry-specific education is a valuable approach to screening in many fields. Formal education can provide opportunities to develop knowledge and skills and also evaluate performance ability and encompass it within the GPA academic performance metric. Involvement in a formal academic program also indicates industry-specific motivation. However, despite the attractions industry's size, diversity, and innovation, postsecondary degree-level education specific to the industry is scarce.

It may seem that the laws of science, technology, engineering, and mathematics are the same regardless of the application domain, but it is beneficial for students to understand about the industry, its state of the art and its practices, constraints, and standards, and in turn to have a credential affirming that understanding. However, there are no established programs of engineering design and technology that offer students industry-specific training. Some engineering and technology projects or single courses are offered, such as the occasional Roller Coaster Dynamics course at Purdue University [27].

Several post-secondary programs focus on operational management of theme parks and attractions. Rosen College of Hospitality Management at University of Central Florida (Orlando, FL) offers a Theme Parks and Attractions track for students of its Bachelor of Science in Hospitality Management. Breda University of Applied Sciences (Breda, Netherlands), offers Attractions and Theme Parks Management as an English-taught baccalaureate programme. San Diego State University's School of Hospitality & Tourism Management offers executive education programs associated with IAAPA. Other programs focus on the design of attractions, such as the Master of Fine Arts (MFA) in Themed Entertainment Design offered at Savannah College of Art and Design (Savannah, GA) and MFA in Themed Experience at University of Central Florida (Orlando, FL). IAAPA Foundation's Academic Advisory Committee (http://www.iaapa.org/iaapa-foundation) and the newly established Themed Experience and Attractions Academic Society are working to identify post-secondary programs and courses.

B. Post-secondary institution student clubs

Students at an increasing number of universities have formed extracurricular clubs to bridge curriculum and industry interests. Clubs vary in the activities they undertake, choosing locally specific combinations of what may be described as "enthusiast" activities, "technology" activities, "production" activities, and "networking" activities. The next sections will elaborate on this activity typology and the potential the various activities offer for participants to acquire work-related knowledge and skills and produce evidence of performance. While all extracurricular clubs show interest and initiative, the activity level and productivity of a club may reflect transient club size and composition more than aptitudes of individual students.

1. Enthusiast activities

Enthusiast activities express members' appreciation for themed entertainment as a product. Members may visit attractions, invite speakers for "insider" insight about notable attractions projects, and design or simulate whole attractions using various materials including games, toys, software, and artwork. These activities do not provide evidence of work quality for most fields because internship and early-career skill sets do not typically entail concept development and master planning of whole attractions projects except in junior roles and in specific academic fields, rarely engineering. Enthusiast activities can be beneficial to club spirit and membership development, as students with solely enthusiast interests may join along with students with professional aspirations. These projects can demonstrate passion for the industry, and soft skills such as teamwork and leadership, if an individual student's contribution can be discerned.

2. Technology activities

Technology activities learn about and work on projects inspired by industry technologies. These activities can relate students' academic learning to industry-relevant design and technical applications, through building models of technical systems, using programmable logic controllers to control a scale model of a ride, or constructing a bench-top model of linear induction motor propulsion. Ambitious clubs may design and build models that innovate new systems. The scale of projects is limited compared with full-scale industry projects, but successful projects may be useful evidence of work proficiency if individual contribution can be established. Technology activities may primarily appeal to disciplines related to the activity, so multiple technology activities, or other types of activity, would be needed to sustain an interdisciplinary club. The club may lose momentum on completion of the technology activity, or graduation of the project drivers. Therefore, centering a club on technology activities may hinder recruitment and compromise the club's long-term viability unless the club establishes a continuity strategy.

3. Production activities

Production activities involve producing a themed attraction. University theme park clubs have produced haunted houses and even dark rides. Like campus theatre productions or fashion shows, producing an attraction for a local audience requires a variety of skill sets. Collaboration among students from multiple disciplines on a common mission provides an opportunity to learn about complementary disciplines and communicate across professions. If a production is produced by students from a single academic discipline, some will be producing work that does not provide evidence of their skills in their own field. As such, there may be limited career benefit to them. Participation in production activities is an opportunity to demonstrate persistence and leadership skills. It may be difficult for clubs to attain the capacity to undertake production activities because the activities require committed space, time, and materials and a sufficient production team size to be successful.

4. Networking activities

Networking activities are those that place the members in proximity of practising professionals to facilitate school-to-career transitions. This may include guest speakers about career topics, mentoring programs, and opportunities for job shadowing. In contrast to guest speakers as an enthusiast activity, networking guest speakers focus on professional development topics rather than behind-the-scenes stories of popular projects. Networking activities provide opportunities to learn and demonstrate soft skills but do not enable evaluation of work skills in technical fields.

C. Industry educational experiences

There are several educational experiences offered through the industry, and this section will briefly refer to three prominent opportunities: educational programs of the Themed Entertainment Association (TEA), programs of IAAPA, and student outreach of ASTM Committee F24.

1. TEA SATE and Summit educational programs

The Themed Entertainment Association (TEA, http://www.teaconnect.org) operates a "NextGen" program and educational conferences and numerous networking events on a global basis (www.teaconnect.org/nextgen). TEA NextGen encourages post-secondary student groups and can often provide speakers for the groups. TEA's educational programming includes notably the SATE conferences and the TEA Summit (http://www.teaconnect.org/Events-Education). These events feature keynote presentations on emerging trends and case studies of significant projects, many posted on the TEA YouTube channel. While engineering students and young professionals are welcome and do participate, the programs of activities focus on design of storytelling experiences and environments. Technology seminars generally focus on technology as a medium or tool, and not entry-level technical knowledge for engineering and technology professions. SATE attendance is an indicator of interest, but involves no evaluation of learning outcomes or work abilities.

2. IAAPA educational programs

Many students interested in the attractions industry attend an IAAPA Expo: conferences held around the world, the largest of which is held in Orlando, Florida annually in November. Some students participate in the entire three- or four-day duration of the event, while others attend for a day or two. IAAPA offers a Young Professionals program and other educational programming providing knowledge about the industry (http://www.iaapa.org/about-iaapa/membership/join-iaapa/membership-dues/young-professionals). Attendance demonstrates interest and commitment, but involves no evaluation of the student's abilities or potential.

Students with limited time onsite at IAAPA's conference will often focus on touring the exhibits with hopes of meeting and impressing exhibitors who might be potential employers. This is often a counterproductive strategy. Although manufacturers and suppliers are interested in future interns and professionals, their goal for IAAPA Expo is to exhibit and sell their products and services. Amidst the physically and mentally demanding schedule of exhibit hours and networking events, most exhibitors have a low capacity for talent acquisition at the conference.

IAAPA also offers a limited number of student opportunities to attend Expos in an unpaid "Ambassador" role. Ambassadors assist participants with directions, scan badges in to education sessions, and similar functions that may provide some exposure and opportunity to meet established professionals and hear expert presentations (http://www.iaapa.org/expos/show-ambassador-program). Ambassadors may receive performance evaluation and professional reference, but Ambassador skill sets align more closely to hospitality roles and less with engineering and technology careers.

3. Committee F24 student outreach

Owner/operators of theme parks and manufacturers and suppliers to the industry regularly meet up under the auspices of industry organizations including ASTM International Committee F24 on Amusement Rides and Devices. Committee F24 involves professionals in design, manufacture, inspection, maintenance, and operation of amusement rides and devices to develop consensus standards that will ensure safety to personnel and the public [28]. Between formal meetings, professionals also discuss many common interests. Among the common interests in the past 10 years has been the need to develop the "next generation" of engineers. Committee F24 established student information sessions in connection with F24 meetings twice per year. Initially, fewer than 10 students attended, but in recent years, 80 or more students have participated from universities around the world. Committee 24 meetings also offer group sessions with general career advice for students, two group social networking receptions for participants including students, plus a networking luncheon for women including female students.

Students attending F24 meetings have incurred travel expenses and must make up missed work from at least three days of classes to attend the full conference, which indicates strong motivation. Employers also recognize that observing and interacting at these meetings provides exposure to knowledge not taught in academic programs about the thought process of designers and operational considerations, and the specific standards applicable to engineering design of rides and attractions. For these reasons, many interviews are held between hiring managers and internship seekers concurrent with these meetings. Beyond an impression of the student's interaction, however, employers have no opportunity or mechanism to evaluate students' learning from this experience or their work abilities.

III. RYERSON INVITATIONAL THRILL DESIGN COMPETITION

A. Origin and overview

Ryerson University, a public university in Toronto, Canada, was established in 1948 and now has a student body of some 40,000 students. The THRILL Lab, which focuses on human factors and amusement attractions was established in 2001 (www.ryerson.ca/thrill). By 2013, dozens of students from Engineering and other academic programs had worked on lab projects and participated in guided field trips to the Canadian National Exhibition to learn about the structure and mechanisms of mobile amusement rides, attended IAAPA and ASTM F24 meetings, and several students had set personal goals to work in the attractions industry. Early in 2014, it was decided to produce the first Ryerson Invitational Thrill Design Competition (RITDC) to focus primarily on engineering design specific to the attractions industry.

One of the original, broader motives for the competition was to provide a learning experience that emphasized human-centred design, reflecting the author's expertise as a Professional Engineer specializing in human factors engineering. The attractions industry provided an ideal application domain because effective human-centred design is critical to the attraction industry's economic welfare, to attract and entertain guests and keep them safe and comfortable. While guest safety is essential, amusement also requires the guest to enjoy the experience. This highlights the important principle that design does not work unless it works for the user. Despite its importance to effective design of products and systems, outside of Industrial Engineering programs, most engineering programs contain little or no curriculum in human factors engineering [29]. A focus on technical function can result in designs that must rely on documentation, labels, and user training to ensure the correct use of the designed equipment. As such, knowledge acquired through the learning experiences of the competition should benefit all engineering students and improve the systems they design, even if ultimately practising in other sectors.

In relation to the attractions industry specifically, the competition intended to prepare students to secure internship opportunities: acquisition of attractions-industry knowledge and skills related to internship and entry-level positions, production of evidence of performance ability, and demonstration of motivation and passion for the industry. As tabulated in Table 1, the structure and scale of the competition has evolved and expanded over its four editions to date, incorporating observation and feedback.

The design challenges are deliberately not a "hackathon" to solve specific real problems. Although each design challenge is contained within a specific case or application as a hypothetical, the challenges simulate design decisions that designers often encounter in their unique projects, and solve in various ways. The challenges are focused, such as rider restraint and containment in a specific context or mechanical design to produce a certain ride action. The challenges, like real design environments, have no predetermined ideal solution, and may have no perfect solution at all. The judges observe how the teams understand the challenge, translate it to a design problem, and approach problem solving, including their consideration of multiple options. Solutions also show their knowledge of the technologies they use in their chosen solutions, and how they adapt to various pressures imposed during the competition. Short preparation time is one notable pressure, with some challenges received only upon arrival, leaving teams 18 to 48 hours to revise or completely solve the challenge. The second pressure is the "twists", or additional and changed information about a challenge that has been partially prepared ahead. Design professionals confirm that twists are a business reality. While the timeframe of design revision is greatly compressed in the competition, the twists are considerably less extensive than the actual specification changes in real projects.

The competition is also not intended to be a "fantasy camp", where mechanical engineers would pretend to be business executives planning entire theme parks or art directors choosing set design and themed dining experiences. Instead, challenges were intended to enable demonstration of proficiency with entry-level engineering skills, accentuated with creative ingenuity and insight into the nature of the business. Visual communication, including artistic skills and understanding of the use of storytelling in themed entertainment, enhances an engineering presentation. However, out-of-discipline skills do not replace in-discipline skills as evidence of knowledge and capacity for discipline-specific internships. As the competition evolved and incorporated challenges broader than engineering, it created incentives to build interdisciplinary teams. The following sections describe the evolving form, scope, and scale of the competition, year by year.

B. Year to year evolution

1. RITDC14

RITDC was first held in 2014 onsite at Ryerson University. Initially created as an engineering competition, sponsored by the Faculty of Engineering and Architectural Science and directed by the author, the competition consisted of both partially prepared and impromptu challenges. Participants were required to be full time students from the same university including any affiliated colleges, and it was recommended that teams include engineering students, though no restrictions were imposed on program of study.

Feature	RITDC14	RITDC16	RITDC17	RITDC18
Location	Toronto / Canada's Wonderland	Orlando / Universal Orlando	Orlando / Universal Orlando	Orlando / Universal Orlando
Days excluding welcome evening	2	2.5	3.5	3.5
Tours and park access	Most of day, 4 spots	Morning tour, 3 spots; 3-day park access pass	Morning tour, 3 spots; 3-day park access pass	Morning tour, 3 spots; 3-day park access pass
IAAPA Expo	Begins two weeks later, requires separate trip	Begins day after competition; same city	Begins day after competition; same city	Begins day after competition; same city
Learning opportunity: Access to expert feedback	Students received only own feedback	All teams watched all presentations and received all feedback	All competing teams watched all presentations in same sessions and received all feedback	All competing teams watched all presentations in same sessions and received all feedback
Learning opportunity: Educational material	Faculty subject matter interpreters on tour	Reading material sent to teams prior to competition	Reading material sent to teams prior to competition	Reading material sent to teams prior to competition
Evaluation: **Internship screening**		Internships for winning team and others	Internships allocated on individual basis	HR presentation and internships
Evaluation: **Judges**	Assorted industry and affiliated	Sponsor's internal professionals	Sponsor's internal professionals + External manufacturers/ suppliers	Sponsor's Internal professionals + External manufacturers/ suppliers
Challenges	3	3	8 (one challenge had legacy/ new team variants)	9
Teams	4 plus one remote	4	8	12
Students	20	24	48	86
Challenges per team	All 3	All 3	Up to all 8 challenges	Up to 5 of 9 challenges
Teams per challenge	All	All	Up to all 8 teams	Maximum 8 teams
Students per team	5	6	Discretionary	Up to 12
Professional scope	Engineering / human-centred	Engineering / human-centred	Engineering/ human-centred, Artistic	Engineering/ human-centred, Artistic, Business
Awards	Per challenge and overall	Per challenge and overall	Per challenge, plus engineering, artistic, overall	Per challenge, plus engineering, artistic, overall
Tournament points system	Not used	Not used	Introduced, points for all ranks plus opportunity cost supplement	Points for top three ranks, opportunity cost supplement capped at 5
Theme (IP – intellectual property)	No guidance. Students superimposed own choices of IP, sometimes not appropriate.	Instructions cautioned to use public domain or IP available to sponsors.	New public domain "Magic Land" IP created and assigned.	"Magic Land" IP expanded and revisited.
Challenge topics	Re-imagine classic ride for wider demographic / human centred design of experience NoLimits roller coaster model with assigned specifications provided on arrival Communicate educational benefit for engineering students to learn about attractions design	Restraint and containment challenge (prepared in advance) NoLimits roller coaster model: assigned specifications and twist on arrival Re-imagine classic ride for wider demographic	Restraint and containment challenge (prepared in advance) NoLimits roller coaster model: assigned specifications and twist on arrival One of Re-imagine classic ride (first time teams only) or Mechanical design challenge Queue design (environmental storytelling) – prepared + twist Patron behaviour-shaping (human-centred design of experience) Freehand landscape rendering (concept art) of assigned scene Rider accommodation design (accessibility) Themed land design (layout/ capacity and artistic) – prepared with additional specifications on arrival	Restraint and containment challenge (prepared in advance) Freehand rendering concept art of assigned emotion, free choice of scene NoLimits roller coaster model: assigned specifications and twist on arrival Attraction design challenge (dark ride) – prepared + twist Accessibility and accommodation challenge Mechanical design challenge Experience design challenge (human-centred design) Retheme existing ride (theme and show) Reimagine existing land (layout/ capacity and artistic design, and business case for area) – prepared with additional specifications on arrival

Table 1. Evolution of competition features

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Participants arrived for an evening welcome followed by a two-day program. On the first day of the competition, they attended tours at Canada's Wonderland theme park north of Toronto on a day when the park was closed to the public, but was staffed for the tour, and to prepare for guests later in the day for Hallowe'en haunts. The tours were enhanced by having industry and academic experts present to interpret the technology and experience as groups visited each stop on the tour. Teams then returned to their accommodation to design and prepare their presentations. Two challenges involved designing, one a roller coaster, and the other a human-centred re-imagining of a classic ride. The third challenge was a communication challenge. Competition rules prohibited seeking or receiving any advice or coaching from professionals (including professors, teaching assistants, supervisors from past or current work, or even family).

Four universities attended in person, including two with established theme park design clubs. A fifth club from a U.S. based university presented their solutions remotely over an Internet connection. Diverse judges attended to evaluate the solutions presented on the second day. The first two challenges were judged concurrently by judging panels in separate locations, and teams presented in series and did not see each other's presentations.

In relation to the competition goals, the competition clearly presented learning opportunities, through tours, learning experiences of the design challenges, and feedback from judges. However, because clubs moved from one judge panel to the next and were working on future presentations in between, students did not have the opportunity to learn from observing presentations from other teams, hearing feedback on other designs, or why specific teams won specific challenges. This format limited knowledge and skills acquisition. Also, the club that presented remotely did not benefit from the learning exposures during the tour and networking.

Attendance could be indicative of motivation to design for themed attractions, particularly for teams that already had an industry-focused club. However, it was not clear that local teams were interested in the attractions industry specifically, more than as a general engineering competition. Several U.S. based clubs actively interested in themed attractions were invited but did not accept the invitation; attending a competition in Canada may have been problematic.

Most significantly, the competition enabled industry judges to directly evaluate presenters' skills. This advantage was the primary impetus in the next steps with RITDC.

2. RITDC16

In 2015, no competition was organized, as the author as producer/director took sabbatical leave and engaged with the industry in other ways. During this period, Universal Creative™ suggested relocating RITDC to Universal Orlando Resort™. This overture was in the context of established relationships between the author and Universal Creative professionals through IAAPA, ASTM Committee F24, and other mutual interests, and the previous experience of Universal Creative's executive champion having judged RITDC14. Canada's Wonderland had provided hospitality, proximity to campus, and Ryerson alumni and seasonal employment connections, but competition scheduling was complicated by seasonal closings and cool temperature for later parts of the Fall semester. Universal Orlando operates year-round with generally more amenable weather in the Fall. Relocating to Orlando made it possible for Orlando-based designer/engineers to participate as judges and also eliminated international travel obstacles for U.S. university clubs. Ryerson Faculty of Engineering and Architectural Science continued to support the administrative aspects of producing the competition.

The most significant benefit to Universal Creative was the opportunity for judges to directly evaluate student ideas and execution. To maximize this benefit, we agreed to schedule the competition consecutively to IAAPA Expo, so more prospective judges would be likely to be in Orlando to attend IAAPA Expo and available to assist with judging. The consecutive schedule also permitted RITDC participants to attend IAAPA Expo without additional airfare, simply incurring additional nights of lodging. IAAPA provided a student-discount code for participants.

RITDC16 maintained the three-challenge format from the original competition. To allow all teams to see all presentations, the schedule was extended a half-day from Thursday arrival/Friday/Saturday (2014) to Friday arrival/ Saturday/ Sunday/ Monday morning (2016) with IAAPA Kickoff on Tuesday. Four universities participated, with a total of 24 participants.

One challenge was revealed and prepared entirely in advance so that it would be judged more heavily on presentation and communication skills. One challenge was prepared partially in advance with a "twist" revealed on arrival. A third challenge was revealed after a guided park walk on the morning of Day 1, which provided some foreshadowing of the challenge. All teams participated in all challenges, and were expected to observe all other team presentations and learn from all the feedback.

Judges were not provided with a rubric, and as colleagues of one another, readily devised rubrics for each challenge based on the prompts provided. For instance, criteria included innovative, effective (solved what was asked), and communication in one challenge, and pitch, story/experience, technical (G-force, restraint, reach envelope, capacity and standards compliance), business, and demographics for another. In at least one case, having set the criteria, judges preferred one solution but determined that another won "on a technicality" based on parsing the specific language of the challenge. Note was taken of the need to anticipate judging in planning the next edition of the competition.

Teams stayed onsite at Universal Orlando Resort™ and did groupwork and presentations at the office meeting space of Universal Creative™ on the two weekend days, with the final challenge presentations at a dining venue at Universal CityWalk™, where the awards banquet was held. Universal Parks & Resorts provided park admissions for participants to return to the park for inspiration and make observations to inform their design work, and following the awards, to appreciate the experience. Universal Creative™ also offered internships to members of the winning team, and some other participants based on performance. Intern placement was significantly aided by senior engineering decision-makers participating as judges, giving feedback, and assessing possible interns during presentations.

The new model met all three major objectives for helping students to become competitive for industry internships: it demonstrated participants' motivation (by travelling to the competition and undertaking the intense onsite experiences), supported acquisition and development of knowledge and skills (through the guided tour, the challenges themselves, and judges' feedback), and enabled employers to evaluate performance to the degree that some interns were placed.

It was clear that storytelling and artistic aspects were fun for participants. However, these aspects have a limited benefit for evaluating qualification for engineering internships, as these functions typically fall under the scope of work of other professions. Rather than discourage consideration of these essential parts of themed entertainment design, we decided to encourage interdisciplinary teams for the next edition of the competition.

3. RITDC17

The third edition of the competition returned to Universal Orlando Resort™, with presentations at dining venues in Universal CityWalk™ that were closed to the public during the day. Groups worked on challenges in their suites at the onsite hotel. Participants also had the opportunity to attend a one-hour mixer with several hundred TEA professionals between morning presentations and an afternoon set aside for groupwork. The competition also built in the discounted IAAPA membership and registration to the competition fee, streamlining access to this educational opportunity. Universal Parks & Resorts again provided park admissions for participants for competition research and experience.

The competition expanded in several ways. The program started a day earlier to accommodate a program of eight challenges in which teams could enter three or more. Challenges were expanded to include artistic/creative subjects, and challenges that would benefit from collaboration of technical and artistic disciplines. All of the previous clubs returned. With the participation of new clubs, attendance doubled to eight teams, 48 participants. Teams were required to have at least two members but maximum size was left to teams to determine based on affordability and available participants. The cohort of judges also expanded to include more Universal Creative™ professionals and senior professionals from major manufacturers and suppliers.

As before, one challenge was revealed in advance (one month), some were previewed a week ahead but a "twist" was revealed on arrival, and others were revealed only onsite. In addition, during the challenge reveal period, some reference and reading material related to attractions design was posted for the teams to review. Some readings would make it easier to adjust to the twists or onsite reveals, such as designing to shape rider behaviour, but the relevance of specific readings was not indicated.

The competition co-directors met in advance to develop rubrics for the challenges. Criteria were customized to the challenge. For instance, a challenge prepared entirely in advance had half the points for presentation, and the other half for technical merit (i.e., effectiveness to solve the stated problem and not create new operational problems, safety problems, guest dissatisfaction, or unreasonable costs). A mechanical design challenge was evaluated on technical feasibility of mechanical and structural design, clear documentation, use of appropriate ASTM standards, safety, comfort, and inclusion/accessibility, use of an appropriate theme, well rendered (freehand or digital), and clear presentation including leading alternatives not selected and rationale for choice of final option. A challenge to design a themed attraction queue was evaluated on the design meeting or exceeding the required number of different show elements, feasibility of guest flow through the space, renderings including plan and perspective views representing the design and the theme, and communication of rationales for design choices in a clear and engaging presentation. Criteria were grouped in relation to three tiers of weight, determined by the co-directors. Judges rated each criterion equally, with weights applied after judging, to determine team standing.

With nine challenges to schedule, some challenges were presented concurrently, with a technical challenge in one venue and an artistic challenge in the other. Attendance at all challenges was not mandatory, except that participants entered in a challenge were required to remain in the venue for all presentations, to incentivize learning from feedback on all solutions to the same challenge, and not just their own. Recognizing there was an opportunity cost of having those members unavailable to work elsewhere on other challenges, the number of tournament points reflected both the team's placement in the challenge and the number of team members present for the full session.

Judges again were complimentary of the experience and exposure to the challenge presentations, and a number of interns were placed with participating companies. Judges did note that sessions with all eight teams presenting were the most difficult to evaluate, and recommended that eight presentations per challenge should be the maximum regardless of growth in the overall competition. The criteria were noted to be too structured for the judges. Quantitative rating of each criterion for each presentation prolonged deliberations and more importantly, discouraged judges from raising additional considerations based on their professional experience.

The perceived value to participants was best reflected in the return of all eight 2017 teams for RITDC18. That said, some clubs were less favourable about larger teams being able to enter more challenges and thereby accumulate more points toward Overall Winner. It was intentional to incentivize teams to have interdisciplinary composition when entering interdisciplinary challenges, but it was not intended to reward sheer size of a team. The trophies themselves do not serve any of the program objectives (provide learning, enable evaluation, show motivation) but teams often use trophies to justify their sponsors' investment in their participation. As such, the "tournament points" system determining trophy allocation needed some adjustment to ensure it was fair.

4. RITDC18

The fourth edition of the competition maintained most features of the third edition, except there was no TEA mixer on the program. The program continued to open with a Thursday evening welcome and conclude with Monday awards luncheon. Universal Parks & Resorts again provided park admissions for participants for competition research and experience. More new Universal Creative judges were added, Universal Parks & Resorts (operations) professionals were added, and more manufacturer and supplier judges joined. Universal Creative Human Resources professionals presented an educational session to assist prospective interns in their internship search. Reflecting the formal expansion to an interdisciplinary focus, Ryerson International assumed support of the University's production functions. The competition was mentioned at the ASTM Committee F24 meeting in February and several teams requested invitations, with the result that student participation nearly doubled again, with 86 students (exceeding the target of 80), representing 12 universities, including all legacy teams and four new universities. Team size was capped at 12. (A team expressed interest in sending an entire graduate class cohort but was limited to 12.) The competition filled in June, with additional inquiries added to a waitlist for future editions. At this point, RITDC accounts for 20% of IAAPA student membership growth (Hallenbeck, personal communication).

Nine challenges were offered. As a new policy, the competition allowed a maximum of five challenges per team for several reasons: to implement a maximum of eight teams in any challenge, avoid overloading smaller teams with too many challenges to enjoy their experience, and equalize eligibility for the Overall Winner trophy. Teams preregistered for specific challenges as early as April, based on the professional mix of team members anticipated the following Fall, and challenges were allocated in order of preregistration. When some challenges filled, subsequent teams selected their most preferred among the challenges with space remaining.

In lieu of a rubric, judges received an overview of the intent of each challenge and a description of how long participants have had with the challenge to provide context for the solutions they would see. The judge panel received a set of cards representing the teams entered in the challenge, and an assignment to rank the top three teams. Following all presentations, panels of five or six judges used the cards to deliberate on each design in a holistic way, arranging and rearranging the ordering of the cards as they pointed out commendable aspects and weaknesses of the various solutions until consensus was reached. Judges had lively discussions reflecting the diverse priorities of different stakeholders for each challenge, ranging from technical function, reliable safety, maintainability, and cost justification, to operational implications and effects on guest interactions. The relative importance of "blue sky" innovation versus cost and theoretical hourly ride capacity varied from panel to panel, even for the same judge. The next edition will incorporate those observations into the judges' briefing to increase consistency.

Tournament points toward the overall champion trophy and the technical and artistic sub-championships were awarded only for the top three placements, and to be fair to smaller teams, opportunity-cost points for members present for the session were capped at five members. Part-way through the competition, some teams asked that these points consider team members in both venues of concurrent presentations. We maintained the announced scheme for the subsequent challenges, but agreed to consider this for the future.

As the challenges diversified, we noticed in this edition several instances where a team's solution relied on strategies outside the field of training of the members involved. While this can show "out of the box" thinking, it has two limitations. First, without a team member from the other field, the design idea may lack advanced or even basic knowledge needed to fully evaluate the merit of the proposed solution and develop it properly. Second, presenting such a solution does not enable judges to evaluate the capacity of the students in their actual field of training, which is the basis for prospective internships. Note was taken to require teams to ground their designs within the disciplinary context of team members, providing that broader solution sets would be welcome provided the team contained members with the disciplinary expertise applied.

C. Administrative and logistical challenges

The competition continues to adapt and learn from year to year as it encounters various administrative and logistical challenges.

In early editions, some participants gave media interviews following the competition, not only spoiling the substance of specific challenges for future use, but were represented by the media as solving the sponsors' problems. Students understandably want to celebrate their participation and especially their achievement, particularly to thank their institutional sponsors. Media coverage suggesting that large, sophisticated, and globally recognized operators would turn to undergraduates to solve intractable design or operational problems could create harmful public impressions and discourage future sponsorship. This has been an opportunity to educate participants about Non-Disclosure Agreements (NDA), ubiquitous in this innovative industry. Media guidelines and information releases are still evolving.

The schedule requiring participants' absence from regular classes has sometimes been challenging. While we have offered to supervise tests scheduled during the competition, most students have negotiated make-up tests with their professors. However, some participants did not request academic consideration early enough to satisfy their professor, or the professor disapproved of the timing or the duration of the proposed absence. Some have been compelled to return immediately after the awards luncheon, missing the "reward" park time and the IAAPA program. As the availability of judges and indeed the timing of the IAAPA Expo is not flexible, it is not possible to accommodate professors' suggestions that the competition be held during the mid-year break or reading week. This resistance is not a judgement about the educational value of the competition: a class focusing on themed entertainment sought to enroll the entire cohort in the competition. Professors in unrelated, even adjacent, courses may not share the students' appreciation for exposure and potential internships in this industry. We are exploring other forms of academic liaison, better documenting the alignment to conventional learning goals.

Following individual institution policies, some teams have sought a breakdown of registration fees to ensure they were not reimbursed for ineligible items, which varied from team to team. In each case, per-person cost excluding ineligible items have exceeded the registration cost net of sponsorships. Although the registration cost is greatly mitigated by sponsorships, teams also incur different amounts of travel expenses per person depending on how far they travel to Orlando, and whether they fly or are close enough to drive, and how much of IAAPA Expo they stay to attend. Students obtain their funding in a variety of ways, including university/ faculty/ program support, student organization support, personal funding, fundraising activities, and even crowdfunding. Some clubs have free latitude to fundraise any way they wish, while others are limited by institutional policies.

Some associates of teams, including family and university faculty/staff, have requested to observe the competition. This has not been permitted, nor is it being considered, for several reasons. The competition outcomes—from trophies to professional opportunities to confidence and clarity of career goals—speak for themselves, so concurrent observation is redundant. Industry partners' confidence in the integrity of the competition would be compromised by any suggestion that a team's solution could have been coached by non-participants, particularly professionals. In addition, involvement of associates would complicate fulfillment of the participant agreement covering intellectual property and non-disclosure, and could lead to plagiarism of the competition itself. No teams have indicated that observation is needed for chaperoning.

A complication unique to non-U.S. citizen participants were barriers to internship employment in the U.S. The inclusion of judges from manufacturers and suppliers outside the U.S. has proved to be strategically important, as these exposures expanded internship options.

University staff workload has been allocated to registration and hosting administration such as processing payments and executing contracts for catering and hotel. However, as an extracurricular non-credit initiative, the production and direction of the competition has had no faculty workload allocated to date. Directing the competition has grown considerably from a three-challenge weekend event evaluated concurrently. It is now comparable to a 120-student undergraduate course with over 12 groups undertaking various combinations of nine different group projects and 20 guest lecturers. Much of the production/ direction workload comes from designing new challenges each year to allow repeatability, and creation of hypothetical attractions using public-domain themes in which to situate each year's challenges. Recruiting judges, preparing educational communication for participants, providing evaluation guidance to judges, and liaising with industry partners including the presenting sponsor also demand time and care.

D. *"Stopgap curriculum"*

The competition is addressed to design teams aiming to work in a multi-disciplinary industry domain. Therefore, it does not aim to fulfill an exclusively "engineering" curriculum. Rather, it has taken its cue from the industry subject-matter experts who have judged or described their design workflow. Favourable evaluations in the competition challenges will require knowledge and understanding of the application domain of themed attractions, both ride and show, considerations of story and entertainment brand, and diverse user characteristics and expectations. Teams are guided to use applicable standards, notably those produced by ASTM Committee F24. However, considerable latitude exists for each student to have an individual learning experience. That said, the competition as described above in section III.A complements engineering accreditation expectations well.

For instance, the ABET student outcomes (for 2019-20 and beyond [30]) are briefly paraphrased to (1) solve engineering problems, (2) apply engineering design to specified needs, (3) communicate effectively to a wide range of audiences, (4) make informed professional judgements with societal implications, (5) function effectively on a team, (6) acquire, interpret, and use data, and (7) learn and apply new knowledge.

In the competition, engineering students must use what they are learning in their home program and demonstrate their previous knowledge and industry-specific learning not to a course professor but to industry experts, including highly qualified engineers alongside other professions with whom engineers must engage effectively as collaborators and clients.

Effective communication is a central requirement. Each challenge is presented to judges. Communication includes oral presentation and interaction with judge questions, production of calculations and design drawings, FMEA analysis, animations, and other renderings.

The competition also requires teamwork, among engineers and between engineers and other disciplines. Teamwork is unavoidable under the competition's intentional time pressures, and it is readily evident to judges and to other teams how effective teamwork has been. Some teams do their groupwork in "food court" space at the competition hotel, and teams can often observe other group dynamics from a distance. Both the insight into the process and the observation of the results provide a learning experience for those teams that have struggled.

Obviously, based on its name, the competition particularly emphasizes design. Engineering design has become a critical part of accredited engineering curricula, with Canadian universities requiring no less than 225 academic units (each unit is one lecture hour or 2 lab hours) in engineering design. "*Engineering design integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors. (3.4.4.3)*" The Canadian Engineering Accreditation Board (CEAB) goes on to require a significant design experience, preferably involving teamwork (3.4.4.4). [31] ABET likewise requires graduate competence in design, defined as "*identifying opportunities, developing requirements, performing analysis and synthesis, generating multiple solutions, evaluating solutions against requirements, considering risks, and making trade- offs, for the purpose of obtaining a high-quality solution under the* *given circumstances.*" [30]

The competition challenges are realistic and complex, as are many real design environments. Teams must define requirements, consider multiple solutions, and make trade-offs.

Unlike formal university courses assigning individual marks, competition participants are not evaluated individually. Judges and prospective internship hosts may evaluate individual abilities through each student's role in team presentations.

E. Future plans

At the time of writing, preregistration for the 2019 competition is open by invitation. Capacity has been set at 120 participants and by the beginning of April 2019, preregistration reached 98 participants from 13 teams. The competition will include eight challenges from which teams may enter four, with a maximum of eight teams per challenge. Challenges will again be allocated by team preference, in the order of preregistration. Team size will be limited to nine students, with participants from any one discipline capped at six, to encourage clubs to develop interdisciplinary collaborations on campus.

We continue to explore the best way to support and streamline the task of judges, as they contribute their expertise largely on the weekends. The objective is to facilitate their deliberations and use of their professional expertise, without overly structuring them and having a presentation winning "on a technicality". Ranking the top three presentations proved easier than ranking all presentations, but there are still "colourful" deliberations. It is unclear that a rubric is the answer. The most commendable element of a solution might be something so novel that a rubric could not anticipate it. Judges need to understand the intention and goal of each challenge and the implied design requirements, without a rubric that could unintentionally constrain the use of judges' professional insights. Judges appear to enjoy the experience and interactions within the panels. Many judges have asked to return, and other professionals have expressed interest in joining.

While some educational preparation material has been sent to teams ahead of the competition, teams' use of and benefit from the material has not been evaluated. A more systematic plan and evaluation of this element will be considered. We also are undertaking surveys of student experience, initially with team surveys, and plan a survey of individual "alumni".

IV. Discussion

RITDC has grown exponentially with the support of industry sponsors. Through participation growth and scope expansion, the competition maintained a focus on specific entry-level professional skills in a unique industry by adopting an interdisciplinary structure. Realistic, focused challenges showcase real skill expectations for entry level professionals and interns, not just technical skills and knowledge but also interdisciplinary collaboration, time management, creative agility, and presentation. Judges from Universal Creative and its partner companies take an avid interest in how teams adjust to time pressures, approach problem definition, make trade-offs, and present their proposals. The invitation from Universal Creative™ to hold the competition at their location and their ongoing presentation of the competition enabled exponential growth, access to world-class facilities and expert judges, and a network of internship opportunities not only at Universal Creative™ but at associated manufacturers and suppliers. Competition alumni have taken internships and graduate employment in the attractions industry.

The competition has been successful at its chief objectives, specifically providing knowledge to participants about the attractions industry that is difficult to acquire through formal post-secondary curricula, enabling students to show evidence of their skills in relation to their fitness for entry-level positions or internships, and verifying students' motivation and commitment to industry opportunities. As the competition evolved, it offered a roster of diverse challenges that enabled teams to enter challenges matching the skill set and disciplinary specialization of their team members, from single-discipline focused to multidisciplinary. Judges were able to assess communication skills, poise, and group dynamics through the presentations and other interactions during the competition. The characteristics of challenges, including time pressures and changing requirements, was perceived by sponsors and judges to be a realistic simulation of pressures expected in professional work.

The competition continues to adapt and learn from year to year as it encounters various challenges, ranging from participant disclosures and media, logistics of academic absence and institutional oversight, challenges for teams to cover their costs, barriers to internship opportunities, and growing workload for production and direction of the competition. Through this evolution, the partners remain committed to sustaining and exploring the potential of the competition, whether it remains "stopgap curriculum" or transitions to formal curriculum.

The durability of the industry partnerships indicates that the success of the competition is authentic. The competition is now discussed among industry professionals as valid evidence of motivation, industry awareness, and some ability. The authenticity is further validated by the appreciation of the competition by students in attractions programs or courses.

The competition has been seen as a form of stopgap curriculum, providing a learning experience to compensate for formal attractions industry education that is otherwise scarce, particularly in technical disciplines, but it is largely complementary to engineering accreditation expectations. Further evaluation is needed to understand whether participants experience it as a quasi-curricular activity or merely as an audition for internships.

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Stenzler, Senior Director, Engineering and Safety, Universal Creative, co-directed the challenges and judged the second and third competitions and her leadership is honoured with a challenge trophy in her name. The competition's execution and growth would not have been possible without superlative co-production by Universal Parks and Resorts Senior Director of Global Operations, Standards & Harmonization John Riggleman and his staff.

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Symposium Workbook

Undoubtedly, most everyone here has attended other conferences, and find them to be a source of inspiration and re-invigoration. It is our sincere hope that this event will have the same effect for you as well. It is also our experience—and a swath of education research on learning supports this—that active and goal centered participation in your individual learning aids in "stickier" retention and improves personal achievement more so than passively receiving information or "hoping" you will get something out of your invested time.

Our lives are very full these days, and our brain's ability to keep all of the important "bits" of information—even the most important ones—can suffer recall problems. To that end, we would like to offer the following reflective prompts and organizational pages as a first step toward encouraging you to actively engage with the symposium and its participants and presentations. The following pages were designed to help you manage your newly formed connections, jot down ideas and concepts, or make note of items you want to take action on or investigate more fully.

We have shamelessly borrowed elements of this concept from other workshops and conferences, including the Lilly Conferences on Evidence-Based Teaching and Learning held across the country each year. We encourage you to consider attending a Lilly Conference, as they can be exceptional experiences.

Intentional Symposium Goal

In a brief sentence, set one personal goal for your attendance at this symposium:

What ***one word*** captures the essence of this goal?

Networking

Of all the people I met at the symposium, when I return home **I just have to send a follow up email to**: __________

Name	Institution/Email	Notes/Reason for Follow-up

WORKBOOK

Session 1, "Performance as Pedagogy": Points of Interest

Session 1, "Performance as Pedagogy": Follow-up Action Items

WORKBOOK

Morning Panel, "...an Academic Perspective": Points of Interest

Morning Panel, "...an Academic Perspective": Follow-up Action Items

WORKBOOK

Session 3, “Beauty in Engineering...”: Points of Interest

Session 3, “Beauty in Engineering...”: Follow-up Action Items

WORKBOOK

Afternoon Panel, "...an Industry Perspective": Points of Interest

Afternoon Panel, "...an Industry Perspective": Follow-up Action

WORKBOOK

Session 5, “Experiential Learning/Tool Building”: Points of Interest

Session 5, “Experiential Learning/Tool Building”: Follow-up Action

Session 6, "Engineering Art": Points of Interest

Session 6, "Engineering Art": Follow-up Action Items

WORKBOOK

Post-Symposium Follow Through

Of all the possible follow-up action items, **the one I will act upon in the next 10 days is**:

Of all the points of interest in the symposium, **one that I want to share with a colleague** at my home school/work/professional group is:

Notes and Reflections

Notes and Reflections

Notes and Reflections

WORKBOOK

Notes and Reflections

WORKBOOK

Notes and Reflections

WORKBOOK