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# The Impact of Applied Improvisation on Undergraduate Engineering Students' Professional Development

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**ABSTRACT**

Integrating humanities and arts into STEM has been suggested to better prepare students for the workforce. Studies have shown that improvisation (abbreviated as improv), an educational program from humanities and arts, can potentially improve engineering pedagogy and learning. However,

little is known about improv's impact on developing undergraduate engineering students' growth mindset. Also, more work is needed to evaluate the impact of improv in improving the professional skills of undergraduate engineering students. This study integrated an improv workshop into a summer Research Experiences for Undergraduates (REU) program at a university in the east coast of the United States. A convergent mixed-method design was utilized to evaluate the impact of the integrated improv activity on the professional development of undergraduate engineering students during the REU program. The outcome of this study shows that the REU program, which included improv activities, significantly improved communication skills, students' growth mindset, and collaborative research skills. However, the REU program did not significantly improve the creativity ability of students. It is recommended that undergraduate research programs and engineering instructors incorporate improv activities into professional development and class time and consider implementing principles of improv when designing courses.

**Key words**: Improv, REU programs, Professional development.

## INTRODUCTION

Research Experience for Undergraduates (REU) programs, funded by the National Science Foundation (NSF), provide students with hands-on experiences and collaboration with faculty and other students in a research laboratory. REU programs provide participants with valuable and practical research experiences and networking opportunities. Some potential benefits of REU programs include a broader conceptualization of doing research and an increased understanding of graduate life and future careers. REU programs have helped to produce many positive student outcomes (Follmer et al., 2017; Mabrouk & Peters, 2000; Russell et al., 2005; Zappe et al., 2018), including increased likelihood to attend graduate school and improved research-related skills such as problem-solving, data collection and analysis, and independent research (Porter, 2017; Williams et al., 2016). REU organizers often emphasize specific technical topics, or focus on professional skills, such as creativity (Zappe et al., 2018). In addition to time in the laboratory, the programs often include professional development experiences such as workshops or social networking opportunities. The current study explores how the integration of applied improvisation training (improv-based training in non-theater environments, hereafter referred to as improv) impacts STEM undergraduate students' development of creativity, scientific communication skills, engineering growth mindset, and research skills. A mixed methods approach was used to evaluate the impact of the improv experience on student perceptions of their skills through weekly surveys,

interviews, and pre-and post-surveys. The following sections present a literature review on applied improvisation and research-related skills targeted in the study.

**Applied Improvisation: Definitions and Use in Educational Contexts**

The engineering workplace requires complex skillsets from new graduates that go beyond technical skills to acquiring professional skills. A National Academies report, *Branches from the Same Tree*, urges integrating the humanities and arts with science, technology, engineering, and mathematics (STEM) to better prepare our students for the workforce (National Academies of Sciences, Engineering, and Medicine and Affairs 2018). Integrating humanities and arts with STEM disciplines has improved critical thinking and problem-solving abilities, teamwork and communication skills, as well as motivation and engagement (Liao et al., 2016; Rahmawati et al., 2019). Furthermore, integrated curricula and programs can have benefits for women and underrepresented minorities (URMs) in terms of increased motivation and self-regulated learning (Stolk & Martello, 2015) and improved visuospatial ability (which is correlated with success in STEM) (Uttal & Cohen, 2012). Improv-based pedagogy has been used to empower students who have been traditionally marginalized in STEM and promote culturally relevant teaching and learning with diverse student groups (Boal, 2014; Gaskins et al., 2021). In addition, in the remote learning contexts during the recent COVID-19 pandemic, improv pedagogical techniques modified for a remote context are a potential approach to engage students in active learning and critical thinking (Novick, 2021). Motivated by these positive outcomes from humanities and arts integrative educational programs, an applied improvisation component was integrated into this REU professional development program alongside the technical research experience.

Improv has recently gained attention in several settings, including medical (Fu, 2019; Hammer et al., 2011; Watson, 2011; Watson & Fu, 2016), business (Benjamin & Kline, 2019; Huffaker & West, 2005), information technology (McMahon, 2020), mathematics classrooms (McCloskey & Tanner, 2019), education (Méndez Martínez and Fernandez-Rio 2021; Perrmann-Graham et al. 2022), and engineering (Campbell & Klotz, 2021; Han & Parascho, 2023; Holtgreive 2018; Lavik, 2021; Loftus, 2018; Ludovice et al., 2010; Pulford & Falkenberg, 2016). Improvisation has also been used as a form of inclusive pedagogy (Tanner et al., 2018). Techniques utilized in improvisational training focus on attunement (i.e., the ability to know others, self, and situation), affirmation (i.e., giving feedback to let others know they have been heard), and advancement (i.e., contributing ideas to enrich others and self) which rely on skills such as listening, perception, spontaneity, adaptation, and creativity (Fu, 2019, p. 347).

Applied improvisation training has shown positive outcomes for participants, including enhanced communication and collaborative skills, leadership skills, adaptability, and creativity and promotion of innovation (Benjamin & Kline, 2019; Esposito, 2016; Rossing & Hoffmann-Longtin,

2016). In engineering education, improvisation has been appropriated in different ways to develop professional skills. Communication skills are one of the most targeted learning goals by integrating improvisation. LaMeres, Hughes, and Organ (2019) used improvisational acting techniques to improve engineering students' oral communication to prepare them for the workforce. Brocato et al. (2015) focused on engineering students' presentation skills rather than other forms of oral communication by providing a workshop based on improvisational theatrical performance exercises.

Creativity and innovation are among the most targeted learning goals in improvisation with engineering students. Novick (2021), in response to the COVID-19 pandemic, when many teaching and learning environments were forced to move online, integrated improvisation to develop creativity for engineering students. Earlier, Ludovice, Lefton, and Catrambone (2010) explored how improvisation exercises could facilitate engineering innovation in technical environments. Also, Hatcher et al. (2016) used improvisation games to promote humor in engineering design to increase creativity.

Further studies have used improvisation to improve other aspects of engineering education. For example, Wigner, Halpern, and Record (2018) collaborated with professional performers to integrate improvisational games into the classroom. They reported in their study that their students perceived that improvisation helped to increase growth mindset and other attributes. Pulford and Falkenberg (2016) used improvisation to support active learning pedagogies by working with engineering educators who taught undergraduate and graduate-level courses and focused explicitly on the instructors' perspective in implementing improvisation methods in classrooms. Aiming to improve instruction, Tanner (2019) promoted building a classroom ethos based on improvisation using vroom, an improv exercise in which participants pass imaginary balls of energy around using bodily movements and cues. Tanner (2019) argues that this exercise can be adapted to different disciplinary classroom content or pedagogical purposes.

This study aims to evaluate the impact of an improv experience incorporated into a chemical engineering REU program at the Pennsylvania State University on students' perceptions of their creativity, engineering growth mindsets, and communication self-efficacy. In addition to providing students with research experience, the REU program aims to develop students' collaborative research and communicational skills to prepare them for their future careers through targeted professional development activities. We hypothesize that the applied improvisation techniques will improve the students' self-efficacy for their scientific communication skills, creative self-perceptions, growth mindset, and collaborative research skills. This study contributes to the literature on integrating improvisation with engineering education by implementing improvisational activities into an REU program to develop students' research-related, non-technical

skills, including creativity, scientific communication, and self-efficacy. The following evaluation questions (EQ) were asked:

EQ1 (Quantitative Question) Do students' perceived research experience and skills, communication self-efficacy, creative self-efficacy, and engineering growth mindset increase due to integrating improv activities into the REU program?

EQ2 (Qualitative Question) What are students' perceptions of the improv activities included within the program to potentially improve creative self-efficacy, communication skills, and engineering growth mindset?

EQ3 (Qualitative Question) What are students' general perceptions of their experience and gains from participating in the improv activities during the REU program?

**Description of the REU Program**

The study was part of an REU program focused on integrating Biology and Materials hosted by the Chemical Engineering Department at an eastern university in the United States. The principal investigators for this project have received NSF grants for consecutive years to support multiple REU projects. The REU program is a 10-week-long experiential learning experience. The immersive research training focuses on biomimetics, bioinspiration, bio-derivation, and bio-sourcing, and aims to develop students who will be leaders in the development of biomolecular materials and processes. The program achieves this by providing students with hands-on research experiences and professional development opportunities. In addition, students who participate in the program are mentored by faculty, graduate students, and postdoctoral scholars who are actively involved in research and have diverse research interests. REU participants receive firsthand research experience from the research laboratory where they choose to work. The program aims to provide research experiences to a diverse group of students who do not have prior research experience and/or who come from institutions that lack graduate programs in Chemical Engineering. In 2021 and 2022, applied improvisation was integrated into the REU program.

**Applied Improvisation Workshop**

The applied improvisation element was newly added to the overall REU program, which has run for multiple years and NSF renewals. The improv workshop occurred once per summer, lasted for two hours, and included multiple improv activities. A local improv group led the REU students through various applied improvisation activities. It should be noted that one key difference between the cohorts was the timing of the improvisation workshop. In 2021, the improv

workshop took place during the sixth week of the program, while in 2022, the improv workshop took place during the first week. Students participated in three improv activities during one workshop session in 2021 and 2022. The improv activities were not directly related to specific elements of the REU program or other activities within the program. However, participants were asked to reflect on how they can transfer the improv learning to their research experience.

The first improv activity focused on group introductions. The group assembled into a circle and each person stated their name in an enthusiastic voice. The participants were told to remember one or two names during this time. After each person said their name, one person would say "I am ___ and this is _____" and take that person's place in the circle. Beyond getting to know each person in the group, this activity taught participants to only take in a few names at once and not allow themselves to be overwhelmed with too much information.

In the second improv activity, students got together in pairs with a starting prompt ("It was a Tuesday"). The leaders then asked the shorter person in the pair to say, "It was a Tuesday." The partner then said "Yes..and..." and added something to the story. This continued between both people, and the story evolved. The "yes and..." communication strategy was practiced to encourage listening, acceptance, spontaneity, idea generation, and collaboration skills.

During a third improv activity, five students were asked to come to the front of the group and come up with an innovative marketing advert for a product. The product was suggested by the other students in the program. Each student within the group took a turn in building on whatever the first student had to say. For example, one team was asked to develop a marketing advert for a toothbrush. The five students would sell this special toothbrush. One student said, "This toothbrush has the toothpaste right inside it." The next student said, "Yes, and the toothbrush can brush your teeth for you without holding it," the next student said, "Yes – and the toothbrush even orders new toothpaste when it runs out,"...etc. This allowed students to practice thinking expansively and creatively and to answer questions on their feet. The workshop ended with the participants back in a circle. The improv leader asked the students to reflect on the lessons they could take from the workshop to their research activities.

**Description of Student Participants**

Institutional Review Board (IRB) approvals and consent were obtained from the students before the evaluation study began. Twenty students completed the REU 2021 pre- and post-surveys, and twenty students completed the REU 2022 pre- and post-surveys. In total, forty students completed the pre- and post-survey study. More demographic information for participants is shown in Table 1. Nineteen and twenty students reflected on their improv experience in 2021 and 2022, respectively. In total, thirty-nine students provided reflections on the improv activity. Also, eight and nine participants were interviewed in 2021 and 2022, respectively. In total, seventeen students participated in an interview session.

## METHODOLOGY

### Evaluation Design

A convergent mixed-method design (Creswell and Clark, 2018) was utilized to evaluate the impact of the implementation of the REU on how an applied improvisational workshop influenced students' research skills, self-efficacy in creativity, and communication skills. In a convergent mixed-method design, quantitative and qualitative methods are adopted. A mixed-method study offers the advantage of explanation, corroboration, triangulation, and deeper exploration of the phenomenon (Creswell and Clark 2018; Greene, Caracelli, and Graham 1989).

For the qualitative assessment, structured interviews were conducted to understand students' perceptions and the changes to those perceptions before and after the REU program, as well as students' reflection during the activities. For the quantitative evaluation, the pretest-posttest design was adopted in evaluating the effectiveness of the integrated improv activity into the REU program.

Since we were exploring the impact of the improv intervention across two cohorts, the evaluator tested to see if there was a significant difference between the 2021 and 2022 cohorts. The two-tailed significance test showed that on all the constructs considered except for students' experience with research during the pre-test and post-test, the participant cohort from Summer

***Table 1. Demographic information of participants from REU 2021 and 2022 Cohorts.***

| Baseline Characteristic | Cohort 2021 | | Cohort 2022 | | Combined Cohort | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| Gender | | | | | | |
| Female | 7 | 35% | 8 | 40% | 15 | 38% |
| Male | 12 | 60% | 12 | 60% | 24 | 60% |
| Not listed | 1 | 5% | 0 | 0% | 1 | 3% |
| Race | | | | | | |
| URM | 4 | 20% | 5 | 25% | 9 | 23% |
| NON-URM | 16 | 80% | 15 | 75% | 31 | 78% |
| Year | | | | | | |
| First-year | 0 | 0% | 0 | 0% | 0 | 0% |
| Second-year | 5 | 25% | 3 | 15% | 8 | 20% |
| Third-year | 5 | 25% | 7 | 35% | 12 | 30% |
| Fourth-year | 10 | 50% | 10 | 50% | 20 | 50% |

2021 and participant cohort from Summer 2022 do not differ statistically from each other, and thus, the data can be merged (Osunbunmi 2022; Pallant 2020). The students' research experience scale scores indicated that the 2021 REU cohort started with less research experience than 2022 cohort. However, both cohorts have similar gains from pre- to post-survey. Also, the demography and interview responses from both cohorts were very similar. Hence, combining the data sets would still be appropriate.

### Quantitative Data Collection

The pre-and post-surveys utilizing scales with existing validity evidence were administered online via Qualtrics. The pre-survey was distributed during the first week of the REU program, and participants were encouraged to complete it by the end of the first week. The post-survey was distributed one week before the end of the program, and participants were encouraged to complete it around the last week and after the program had ended. The surveys included items related to demographic information (e.g., name, institution, race, gender, class standing) and scales related to engineering students' research experience and skills (Weston & Laursen, 2015; Follmer et al., 2016; Follmer et al., 2017), self-efficacy in communication (Anderson et al., 2016), creativity (Tierney & Farmer, 2002), and the development of an engineering growth mindset (Zappe et al., 2022). Sample questions from the Survey can be seen in Table 2.

***Table 2. Pre/Post Survey contents.***

| Construct | Measure | Description | Sample Item | Citation |
|---|---|---|---|---|
| **Self-efficacy for Communication** | 11 items | Measures students' reported confidence in communicating about science | "How confident are you that, right now, *you could talk about your research interests with a non-science person?*" | Anderson et al., 2016 |
| **Creative Self-Efficacy** | 4 items | Measures students' reported beliefs about their creative skills | "*I have confidence in my ability to solve problems creatively.*" | Tierney & Farmer, 2002 |
| **Research Skill Gains** | 13 Items | Items that measure student gains in terms of research skills | "How confident do you feel with *Understanding journal articles*?" | Weston & Laursen, 2015 |
| **Broad Research Experience** | 4 Items | A 4-item questionnaire assessing students' broad experiences with research. 5-point Likert scale | "Please rate the extent of your experience *Collaborating with faculty while engaged in a research or related activity*." | Follmer et al., 2016; Follmer et al., 2017 |
| **Engineering growth mindset** | 4 items | Measures students' growth or fixed mindsets relating to engineering | "Please indicate the extent to which you agree or disagree with the following statement: *True engineering ability is innate.*" | Zappe et al., 2022 |

*Note:* Italicized words are example response to the question stem, for which the student gives a Likert-type rating.

### Qualitative Data Collection

Open-response weekly reflection surveys and interviews were qualitative data collection methods used in this study. The weekly reflection survey questions captured students' immediate reactions to the experience, while the end-of-program interviews allowed for a more removed perspective from students. Throughout the REU, students were asked to complete a weekly reflection survey about their successes, challenges, and creative self-efficacy using multiple open-response reflection items.

In the weekly reflection survey administered following the improv workshop, three additional questions were included to obtain feedback on students' perceptions of their experiences with the improv activity. They were: (1) How did the improv workshop make you feel? (2) What are the key takeaways from the improv workshop? Moreover, (3) How might the improv workshop help your research work? (If nothing, type N/A). In 2021, the improv workshop and weekly reflection were implemented in week 6 (out of 10). In 2022, the improv workshop and weekly reflection were moved to week 1 (out of 10).

Interviews were conducted at the end of the REU program by one graduate research assistant and were recorded, transcribed, and coded. The interview started with a general question asking participants to describe their understanding of applied improv in engineering research and then specifically about how improvisation is related to research. Some of the follow up questions included whether the improv session helped them with being more creative, confident, and competent in their communication skills, and why or why not.

## DATA ANALYSIS AND RESULTS

### Normality Result

The Shapiro-Wilk and Kolmogorov-Smirnov tests were conducted to test the normality of the pretest and posttest survey data distributions (Pallant 2020). This is important in determining whether the parametric or non-parametric statistical analysis will be used (Pallant 2020). For the Kolmogorov-Smirnov and Shapiro-Wilk tests, a p-value greater than 0.05 indicates that the data collected is normal (Myers, Wells, and Lorch Jr. 2010). Table 5 shows the result of the normality test conducted. The result suggests that, overall, the normality assumption is fulfilled for most of the construct. Hence, a parametric paired-sample T-test was conducted. Only in the case of creative self-efficacy and the engineering growth mindset in the posttest survey was non-normality indicated. It should be noted that the conservative non-parametric related-samples Wilcoxon Signed Rank Test was conducted for the engineering growth mindset and yielded the same interpretation and implication of outcome with its parametric paired sample t-test counterpart. Hence, we retained the paired-sample t-test. However, for creative self-efficacy Wilcoxon Signed Rank Test and paired sample

t-test yielded different results. The author decided to use the more conservative non-parametric test result interpretation since its data mostly follows a non-normal distribution.

**Paired Sample T-test and Effect Size Result**

For the perception of students' broad experience with research, Table 3 shows a statistically significant difference ($p < .001$) between the mean score of the pretest and posttest. Specifically, there was an overall positive increase in students' perception of their research experience from before the REU program ($M = 8.72$, $SD = 5.50$) to after the overall program ($M = 12.86$, $SD = 4.02$). Table 4 indicates that participating in the REU program with the improv workshop effectively improves students' perception of their research experience with a large effect size (Cohen's $d = 0.95$).

For gains in research skills, Table 3 shows a statistically significant difference ($p < .001$) between the mean score of the pretest and posttest. Specifically, there was an overall increase in gains in research skills from before the REU program ($M = 45.38$, $SD = 7.84$) to after the overall program ($M = 52.21$, $SD = 6.28$). Table 4 indicates that participating in the REU program with the improv workshop effectively improves students' perception of their research experience with a large effect size (Cohen's $d = 1.03$).

For the engineering growth mindset, Table 3 shows a statistically significant difference ($p = .002$) between the mean score of the pretest and posttest. Specifically, there was an overall positive increase in the engineering growth mindset of students from before the REU program ($M = 26.82$, $SD = 3.75$) to after the overall program ($M = 29.23$, $SD = 3.22$). Table 4 indicates that participating in the REU program with the improv workshop effectively improves students' engineering growth mindset with a medium effect size (Cohen's $d = 0.55$).

For communication self-efficacy, Table 3 shows a statistically significant difference ($p < .001$) between the mean score of the pretest and posttest. Specifically, there was an overall increase in communication self-efficacy from before the REU program ($M = 453.87$, $SD = 126.48$) to after the overall program ($M = 558.44$, $SD = 72.99$). Table 4 indicates that participating in the REU program with the improv workshop effectively improves students' self-efficacy in communication with a large effect size (Cohen's $d = 0.98$).

***Table 3. Paired Sample T-test.***

| | Pretest | | Posttest | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | SEM | *t* | *df* | *P* (two-tailed) |
| Experience with Research | 8.72 | 5.50 | 12.86 | 4.02 | 0.72 | 5.73 | 35 | <.001 |
| Gains in Research Skill | 45.38 | 7.84 | 52.21 | 6.28 | 1.06 | 6.45 | 38 | <.001 |
| Engineering Growth Mindset | 26.82 | 3.75 | 29.23 | 3.22 | 0.71 | 3.41 | 38 | 0.002 |
| Self-efficacy for Science Communication for Research | 453.87 | 126.48 | 558.44 | 72.99 | 17.08 | 6.12 | 38 | <.001 |

***Table 4. Effect Size Table.***

| | Standardizer | Point Estimate | 95% LL | 95% UL |
|---|---|---|---|---|
| Experience with Research | 4.34 | 0.95 | 0.55 | 1.35 |
| Gains in Research Skill | 6.60 | 1.03 | 0.64 | 1.42 |
| Engineering Growth Mindset | 4.41 | 0.55 | 0.21 | 0.88 |
| Self-efficacy for Science Communication for Research | 106.68 | 0.98 | 0.59 | 1.36 |

**Wilcoxon Signed Rank Test Result for Creative Self-Efficacy**

A Wilcoxon Signed Rank Test revealed that there was no statistically significant increase in the participants' creative self-efficacy following participation in the REU program that incorporated an improv workshop, $z = -1.95$, $n = 40$, $p = .051$, with a medium effect size ($r = .31$). The median score on the Creative Self-Efficacy Scale increased from pretest-survey ($Md = 15$) to ($Md = 16$) posttest-survey, as a result of the REU program as a whole.

**Qualitative Analysis**

The second and third evaluation questions were answered using thematic analysis to analyze the qualitative data collected from the three open-ended questions in the weekly reflections survey and post-interviews (Braun and Clarke 2012; Guest, Namey, and Mitchell 2013). Kiger and Varpio (2020) six-step thematic analytic framework was adopted. The coders familiarized themselves with the data by reading the transcript over while taking memos. Interview data was open-coded in an iterative process (Saldana 2021). Broader themes were identified initially, and finer codes were identified within the broader themes. Coders were graduate research assistants who have been trained in qualitative research. These coders were supervised by a faculty with expertise in qualitative research.

NVivo qualitative data analysis software was employed as a computer-assisted tool in conducting thematic analysis. The qualitative phase of this evaluation provided a rich, deep description of the students' perceptions of gains from the improv activities. Trustworthiness during the thematic analysis was ensured by fulfilling the criteria of credibility, transferability, and dependability (Shenton 2004). For credibility, authors adopted a well-recognized research method and coders were debriefed by the faculty who supervised them (Shenton 2004). Transferability criteria were fulfilled by establishing study context by giving background information of the REU program and providing description of the participants (Shenton 2004). For dependability, authors followed a logical research process (Nowell et al. 2017). Also, the quantitative phase of the study served as a triangulation for the qualitative phase (Creswell and Clark 2018).

**Qualitative Results**

About half of the respondents across both cohorts were optimistic about their overall experience with the improv workshop and saw the benefits. Some had mixed feelings of being uncomfortable while also enjoying the workshop, and others reported feeling nervous, stressed, or frustrated by the improv workshop. Taken together, the positive effects from the improv activities amplified, and the negative feelings waned out as time went on from the weekly survey to the final interview. One student from cohort one said, "I was very nervous at first, but overall excited." Part of the improv experience is meant to remove participants from their comfort zone, resulting in some initial feelings of discomfort.

In the weekly survey, one student from cohort 2 noted, "Some of [the improv workshop] wasn't bad, some of it was enjoyable as a *viewer*, but a lot of it was very uncomfortable for me because I have some anxiety...it was largely a situation that greatly triggers my anxiety." We chose to highlight this experience to note that some students who struggle with anxiety may find improv activities overwhelming or triggering, and observing the experience of their peers may be more impactful. During their interview, another participant from Cohort 2 noted, "I wasn't super excited going in for the improv workshop, but I felt they did a good job not making it cheesy. It was more structured than the traditional improv. The facilitators were supportive, and I eventually enjoyed it." This experience was similar to others who noted a level of initial discomfort, but through the structured approach and support of the facilitators, they became more confident and expressed an overall positive experience with the workshop. Others noted that they enjoyed the workshop because it provided opportunities for them to meet more students from the REU program (mentioned in both cohorts). It was a good change from the lab experiments (mentioned in cohort 1), and it was already something they enjoyed doing (mentioned in cohort 1). Moreover, the post-interviews on students' feelings about the improv activities, what they learned, and whether the improv training helped improve research or creativity skills indicated that participants' general impressions and feelings about the improv workshop were positive.

Furthermore, the weekly survey and the interviews explored how improv activities related to the growth of professional skills in research. In responding to the second and third questions in the weekly survey (i.e., What do you think are the key takeaways from the improv workshop? and how do you think the improv workshop might help you in your research work?), most students connected the improv activities to a variety of professional skills, specifically "thinking on your feet," communication skills including being and speaking confidently, trusting yourself, being supportive within a team, being more comfortable with mistakes or the unexpected, and being "willing to go with the flow" when thinking on the spot. Students also mentioned being able to build on what others say to promote conversation and idea generation rather than rebutting statements that shut

others off as well as being more confident in asking questions and suggesting off-the-wall ideas that might spark new ways forward. Students also noted making connections in different perspectives and narratives as something gained from the improv workshop. Additionally, one student reported how the improv activities helped them see that "it is important to keep moving despite making mistakes" while another noted, "All of the takeaways [from the improv workshop] I see certainly apply to research because you will have difficulties or failures and you can/need to work with your team to overcome difficulties sometimes."

Specifically, regarding conducting research, students perceived that improv skills, such as thinking on the spot, helped with communicating research results or responding to unprepared questions. Improv skills were also perceived to be helpful in becoming more "observant," telling an engaging narrative about research data, "having the vulnerability to be fine with failures and getting over them together as a team," and refreshing the mind as improv activities were a nice break. Students also noted being more open to sharing ideas and being more confident in themselves. One student took away the following lesson from the improv workshop, "Don't be afraid to look [like] a fool sometimes and try to learn things one step at a time instead of all at once" going on to link it to research by saying, "I probably can't feel any more embarrassed in my lab then I did during the improv at first." Being comfortable with being uncomfortable was mentioned across multiple students in both cohorts as a key takeaway as well as something that was important to help with their research.

The interviews helped to present a more complex understanding of what is mentioned in the survey. Many students still discussed the connection between improv skills and research in different and nuanced ways. The most cited connection was how improv and communication skills in research were connected. What they learned in improv activities about thinking "on the spot" could help them communicate their research progress to their peers and PIs and help them answer questions they had not prepared for when doing presentations. A participant's response from Cohort 1 shows how improv could increase someone's confidence in communicating in multiple ways.

> ".....that includes researchers and scientists in the sense that having those people skills to vocalize what you feel and talking and not being afraid to talk and kind of the confidence to have on stage when you are the person, for instance, giving the presentation or during the Q&A session....."

A related point was raised by some students who saw the connection between the "yes and" activity in the improv workshop to collaboration in research and problem-solving. Two students explicitly talked about how using the "yes and" technique could help build on other research group

members' ideas and work. This connection also applies when students participate in ongoing projects and need to build on existing and new information. A student from cohort 2 noted:

> "We would have to think about what is going wrong, where should we start, how can we pass through this? Moreover, what can we make up on the spot to either establish a goal to continue forward or look more into the problem and think what we should do better or optimize to ensure that the project can continue moving forward."

Another narration from a cohort 1 participant exemplifies this connection and highlights how this student saw the "yes and" technique could help build collaborative projects.

> ".....especially engineering, there is much collaborative work, like collaborating on homework and projects and other things, so I think, with the "yes, and," kind of making sure you are recognizing what your teammates are saying, and you are building upon it and not trying just to push your agenda or just push what your thoughts are or what you are thinking about a certain subject."

One student was more focused on how improv can foster a growth mindset toward failures in research, and another student, when talking about situations where things go wrong in research, perceived improvisation skills can help them be more creative. One participant makes the following comment to show how improv skills, including "yes and" and thinking on the spot, can help with creative problem-solving when faced with failures and mistakes.

> "It is okay if you make a mistake, as long as you can handle it properly, and keep on going and not just give up..... What I liked about it [the improv training] was how you kept rolling with it even if there were mistakes..... There are a lot of on-the-spot, so you must think of something. I think that can help you with your creativity and.....in research.....if you have a plan and it does not work, then you must be creative in thinking of other ways to make it work that maybe other people have not thought of before."

The connection between improv activities and increased creativity was not direct to many students. One student reframed creativity into confidence in that a critical aspect of being creative is to be confident enough to try out and present ideas. This participant commented:

> "I would say yes because I think much creativity is just being confident enough to put your work out there and try something new. So, I think confidence is super key to creativity. So, if you felt the improv helped your confidence, I would say yeah."

However, one student did not attribute any connection between creativity and improv activities. They did say that the improv activities offered opportunities for them to learn different perspectives from other students but did not increase their creativity.

## DISCUSSION

Previous literature has studied the effects of improvisation on promoting students' creativity and innovation, scientific communication and presentation skills, teamwork and collaborative skills, learning from failures, and growth mindset (e.g., Novick 2021; Willoughby et al., 2018; Wigner et al., 2018). This study used a convergent mixed methods design to examine participant students' experience with applied improvisation as part of an REU program and its effects on students' research, communication, and creativity.

Quantitative results showed that students positively perceived their research experiences and significantly improved their research skills during the REU program with the improv activities. This result is unsurprising given the intense hands-on research activities over the 10-week program. The post-interview provided a detailed description of how students considered essential improvisational methods, such as "thinking on your feet" and "yes and," as helpful in developing desirable research skills such as problem-solving, dealing with and moving on from failures, and increases in confidence to speak up about research ideas. Overall, this indicates that improv experiences can potentially have long-term benefits for developing skills in research and collaboration (Benjamin and Kline 2019; Rossing and Hoffmann-Longtin 2016).

The qualitative findings revealed that most students perceived the improvisation techniques as useful to communication skills, including communicating research, building on others' ideas, giving presentations, and responding to unexpected questions. The quantitative result corroborated this finding, showing a significant improvement in students' self-efficacy in scientific communication. This finding confirms previous studies on the positive influence of improvisation on communication skills (e.g., Benjamin & Kline, 2019; Gao et al., 2019; Hughes & Parkes, 2003; LaMeres et al., 2019).

This study quantitatively showed the REU program, which included improv activities, increased growth mindset. This result aligns with Wigner, Halpern, and Record's (2018) study, which found that the improvisation program improved students' growth mindset. The qualitative phase of the study gives deeper insight into how improvisation improves a growth mindset. The participants related that the improvisation workshop fostered a growth mindset toward failures in research and equipped them with skills that can help them be more creative in handling research challenges and with tenacity to progress when failures occur.

However, fewer students related the improv activities during the REU program to increases in their creative self-efficacy from the qualitative phase. Quantitative results showed that students' creativity did not significantly increase because of the REU program that incorporated improv activities. One possible explanation is that it may take a longer time before creativity can be improved. This contradicts a study that suggested that an improv program improves creativity (Hatcher et al. 2016; Rossing & Hoffmann-Longtin 2016).

**Implications for Researchers and Practitioners**

The findings imply the value of integrating applied improvisation to promote professional skills for undergraduate students. However, for students to make more explicit connections between improv and those skills, we present the following recommendations for researchers and practitioners.

First, there is a need for more study on improv interventions within REU programs and the engineering curriculum. For example, experimental research studies where controlled (no improv exposure) and treatment (exposure to improv activity) samples are randomly assigned should be conducted. In addition to this, improv activities that focus on engineering/research scenarios should be considered in future studies. When using improv in engineering education, practitioners can adapt the activities to have the content reflect common topics in engineering research. Also, it is recommended that the improv principles be considered when engineering faculty design their instruction. The three principles of improv are listening, agreeing, and not judging (Drinko 2018).

For example, the "Yes, and..." script can be adapted to various content knowledge. While our workshops chose general starters such as "It was a Tuesday" given that the students came from various labs, this script could be narrowed to reflect a piece of content knowledge if it were to be used in a class focused on specific topics. This would be a direct scaffolding for students to build upon what they have learned in that class and thus encourage knowledge building. A second way to adapt "Yes, and..." is to require students to follow up with alternative perspectives or with evidence or sources of information to support the previous claims. In doing so, students would be engaged in scientific inquiry to develop both creative and critical thinking. The imaginary balls of energy can be used to engage students in many settings, too.

Second, there is also great value in examining the effect of repeated improv interventions and longitudinal reflection opportunities to help students make connections and see implications in the long run. For example, as we have experimented on offering the improv workshop at two different timings in 2021 and 2022, one possible research direction would be to examine when and how often to offer improv workshops during REU experiences to provide the most benefit to participants without overwhelming them.

Third, we recommend designing and sequencing the workshops in ways that closely related constructs, such as creativity and communication skills, complement the improv session and help

students connect the experiences. This will encourage a holistic view of the REU program when integrating an improv session. In an REU program, it is common to offer other workshops focused on communication skills such as how to present scientific work to various audiences; it is important to carefully sequence workshops so that students can enhance their learning.

Fourthly, we recommend that practitioners should consider implementing critical thinking exercises alongside the improv activities. Such exercises will aid the development of students' analytical ability in evaluating the innovation developed during the team improv activities and in their research projects. It should be noted that practitioners should be aware that the initial reactions to improv activities may be negative as improv activities encourage students to leave their comfort zone. Additionally, there may be a need to create compassionate challenges in these spaces for students who struggle with anxiety or provide an alternative approach where students may learn from observing the experience. However, as seen from the survey questions that reflected immediate reactions and the interviews at the end of the program, for many students, the negative impacts seem to carry less impact over time while the positive lesson seems to remain.

### Limitations

One limitation of the current study is that the improv workshop was one of many professional development opportunities provided through the REU program. The program provided another six workshops related to graduate school, future careers, scientific presentations, etc., thus potentially compounding the pre/post-survey results. Without direct measures of creativity, communication, and research as impacted by improv, it is hard to isolate the impacts of improv as students completed a whole program with various learning experiences. However, students were introduced to the local improv community, and a group of students in cohort 1 attended one of their shows after the REU improv activity. Future directions on improving improvisation in engineering education include regularly hosting improv activities and adapting improv program content activities to appeal to and ease accessibility to a broader range of engineering educators beyond REU programs. Also, while improv activities come with potential benefits, it is important to note that improv alone does not evaluate the value and credibility of innovation the team develops. When working with students to develop ideas, it can be important to follow-up idea generation with critical refinement strategies to ensure a viable path forward.

## CONCLUSION

This study examined students' perceptions on improv activities as related to their research skills and other professional skills, as they participated in an REU program in the summer of 2021 or 2022.

Student responses to pre- and post-surveys were compared and student interviews and reflections were analyzed. Overall, integrating an improv workshop into the professional development program for a summer REU program was seen as a positive experience for students. Students noted that the experience helped them feel more confident in their communication skills, grapple with failure more positively, experience gains in research skills, and develop a growth mindset. However, the REU program that incorporated an improv workshop had a limited impact on students' self-perceptions of creativity, but that may point to the need for more creativity training with students beyond the improv activities.

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## APPENDIX

***Table 5. Normality test results of REU participants during pre-test and post-test survey.***

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | **Statistic** | ***df*** | **Sig.** | **Statistic** | ***df*** | **Sig.** |
| Experience With Research | | | | | | |
| Pre-test | 0.089 | 38 | .200* | 0.964 | 38 | 0.250 |
| Post-test | 0.109 | 34 | .200* | 0.964 | 34 | 0.308 |
| Gains in Research Skills | | | | | | |
| Pre-test | 0.115 | 38 | .200* | 0.969 | 38 | 0.367 |
| Post-test | 0.116 | 34 | .200* | 0.971 | 34 | 0.503 |
| Engineering Growth Mindset | | | | | | |
| Pre-test | 0.105 | 38 | .200* | 0.969 | 38 | 0.356 |
| Post-test | 0.212 | 34 | <.001 | 0.875 | 34 | 0.001 |
| Self-Efficacy in Research Communication | | | | | | |
| Pre-test | 0.102 | 38 | .200* | 0.973 | 38 | 0.473 |
| Post-test | 0.086 | 34 | .200* | 0.98 | 34 | 0.783 |
| Creativity Self-Efficacy | | | | | | |
| Pre-test | 0.204 | 38 | <.001 | 0.93 | 38 | 0.020 |
| Post-test | 0.199 | 34 | 0.001 | 0.941 | 34 | 0.066 |

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