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"Give Me Every Idea You Have": Building with Improvisation in Engineering Education

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We engineering educators, as a community, are very interested in active learning pedagogies. Active learning is a very good match to engineering education in part because it is authentic to the working lives of engineers, and thus has potential to help our students to better transfer their education to their post-baccalaureate lives. Yet active learning has a significant psychological barrier to wider adoption. The transition from a controlled, scripted, and familiar classroom experience (i.e. the traditional lecture) to an unscripted, collaborative in-class learning experience is often difficult for instructors and students alike[1]. Active learning’s practice literature and scholarship of teaching sometimes provide ideas about how to manage an unscripted class. Yet we lack a useful language for discussing and methodically improving the social, unpredictable component of our interactive classrooms.

In this regard, we in engineering can learn much from creative performance disciplines. Drama and theatre, for example, have rich histories of intentionally unscripted performances that require an ensemble of performers to quickly self-organize and collaborate toward a shared product—exactly the behavior we’d wish of our active learning students. Within theatre, improvised ensemble performance is most commonly referred to as “improv” (or “impro”). Improv is treated as a skill that can be learned, explicitly practiced, and improved upon [2–5]. Indeed, there is a healthy literature of practice that deals with concepts and methods that help to create stronger improv performances, including improv training methods that drama educators have been using for decades (or longer) to help performers develop their skills. This training can embody a range of formats, many resembling schoolyard games[4]; but nearly all successful improv training activities are united by a common thread of providing a scaffolded opportunity for creative, interactive and unscripted performance within a safe and supportive environment (figure 1).

Figure 1: “Yes, And”, a classic improv activity

There are many variations to this game, but the essential rules are that one player starts a story or scene:

> “There was a giant slug outside our house.”

The other players must add another sentence to the story, beginning with “Yes, and”:

> “Yes, and it was bigger than the man who was holding its leash!”
>
> “Yes, and the man led it into our neighbor’s yard.”

The story continues until someone makes a statement that concludes it.

> “Yes, and the slug lived happily in their treehouse from then on.”

By starting a contribution with “Yes, and”, each player must acknowledge the previous contributions to the story, accept these contributions, and build off of them. This scaffolding makes a spontaneous story much easier to create than an open-ended prompt to tell a story. It also ensures that the players work collaboratively to create a shared story. (Imagine how little cohesion the story would have if the players prefaced their contribution with “No, but”!)

Pioneering STEM educators have been demonstrating that improv methods and training activities have great potential for adaptation to science and technology paradigms. With this paper, we hope to facilitate an easier translation of these improv methods to engineering education contexts—particularly active learning practice, where a framework for considering collaborative interactions would be very valuable.

This paper is not intended as a definitive review of improv or improvisation pedagogy, but rather as a brief primer of actionable principles that are essential to improv and relevant to engineering education. These principles are drawn from practice traditions in theatre and comedy, as well as relevant research and teaching practice literature. To enable straightforward translation of improv principles into engineering education paradigms, we illustrate each principle with examples that are authentic to STEM classrooms, contexts, and pedagogy. In order to provide those authentic examples, we interviewed five STEM educators who frequently and successfully facilitate active learning, and whose practices exemplify important concepts in improv methods (Table 1). These educators discussed facilitating improv activities for ensembles of 4-200 students, including multilingual/ESL learners, spanning introductory to graduate level. We coded these educators' interviews conceptually in order to find themes that are relevant to engineering educators who are interested in trying to use more improvisatory methods in their teaching.

A brief disambiguation of "improvisation"

As others have noted, it can be difficult to have a conversation about improvisation because improvisation can mean several distinct but related things. To most of us, improvisation is an action to spontaneously adapt to the unexpected in real time—an activity that we do every day, most generally at unpredictable times [5,6]. To a drama teacher or performer, improvisation/improv refers to methods and frameworks used to scaffold a successful unscripted performance [4,5]. And to still other educators, improvisation is a vehicle of learning via role performance and play [7–10]. Any one instance of "improvisation" might easily span all three definitions!

In this paper we will focus on the second definition, *improvisation methods*, as they have the most immediate resemblance to the structures of active learning and the most immediate translatability. Improvisation methods also offer a well-developed and actionable set of concepts and terminology that we may find instantly useful toward framing our class interactions.

Table 1: Educators who were interviewed regarding improvisatory teaching in STEM; size and level of the classes they discussed in the interviews; and some of their advice for incorporating improvisational methods into a STEM classroom.

Players	Ensemble	Advice
Dr. Raquell Holmes Founder, improv**science** Assistant Research Professor, Center for Computational Science, Boston University.	Research groups of 4 research undergraduates per semester, often sophomores to seniors.	In order to start, "you invite people to do an experiment with you … to do how you understand it is to be an engineer. … Do it early. Do it very, very early because it will transform your room. You don't have to be an expert. The very fact that people are willing to stumble in front of each other gives you stuff. It'll give the students something."
Dr. Susan Walsh Assistant Professor Department of Biology Rollins College	Classes with up to 24 undergraduate students, from freshman to senior.	You may want to "take a workshop, where you will get a diversity of tools so you can pick maybe one little thing and try it out … you will also have a cohort of people that you can talk to about it … and then maybe you can build from there." You may realize you have already been comfortably using some of the techniques and will be "… more willing to try something new. So, yeah, bit by bit."
Mr. Benjamin Taylor Assistant Director of Education Materials Research Science and Engineering Center University of Wisconsin-Madison	Classes with 25 first and second year graduate students.	When facilitating a game, start by explaining the rules of the game: "certainly the time and place for rules is a STEM classroom". So the students realize they "just have to buy in to a very finite amount of expectations." A good resource is YouTube: "Anyone who's interested—get online, look at how it's very straightforward, and it can result in some really extraordinary things."
Dr. Nicholas Gross Lecturer Department of Astronomy Boston University	Graduate professional development classes with 16 students.	Be aware that the first few times trying new activities you will likely fail, but do give it a few tries, modifying as necessary. Find resources. "There are people out there who do this stuff … don't try and recreate it all on your own." Listen to the students, "be present in the group … seeing what they need". "Take care of the group … warm up before throwing material at people", have a conversation about the broader goal.
Dr. Regina Greiwe Jackson Precalculus Coordinator Department of Mathematics and Statistics Auburn University	All undergraduate levels, up to 200 students.	"Have most of your class well prepared but if you see something that is not working, don't be afraid to try, even if it's going to mess up, because they [the students] are pretty flexible." Collect ideas from your daily life, file it, and build a repository for those days "when you really need to grab their attention".

Offers and generosity

A good starting point for discussing improvisatory theatrical performance is at the fundamental unit of improv: the "offer". An offer is *anything that a player does* that provides something for other players to react to or build upon—and those reactions become subsequent offers. Thus an improvised scene, game, or performance is built upon many offers, much like a building is made brick by brick [2].

An offer can be anything: a line, an action, a facial expression, even stillness or silence. Yet not all offers are created equally, and not all are equally effective. An offer that is too broad, or puts others on the spot, or increases the risk or burden upon the next players, is often referred to as a "dull" or "ungenerous" offer [2,3]. But an offer that reduces others' risk, makes it interesting or fun for them to respond, and generally sets them up to make a successful next offer, is rightly called "generous". In improvised performances, it is the implicit job of all ensemble players to make the ensemble itself look good; therefore, generosity is the goal. Notably, generosity begets more generosity. A single very generous offer can help everyone to bring better offers to share with the ensemble [2,3].

For an illustration of generosity, consider the following two offers:

1. "We're here."

2. "We're finally here at the San Diego Zoo—but I don't see a panda anywhere."

Most people would agree that in a game of pretend, the second offer is much easier to respond to, even though the first offer has more possible responses. That creative second offer also required more cognitive labor to produce. It is often more difficult to make a generous offer than an ungenerous offer. This is as true in life as it is in the theatre. If we reframe day-to-day interactions as offers, it's easy to spot effortless ungenerous offers and their effects. We all know the feeling of being asked, "How was your day?" and reluctantly trying to create and edit a satisfying narrative of our day for another's entertainment and edification; our return offer is most frequently an uninspired "fine".

When we reframe ours' and our students' interactions together as offers, a litany of active learning stumbling blocks take on new clarity. An excellent example of this was shared by Dr. Raquell Holmes, who led a group of four students to write a book on cell modeling over multiple semesters. Intentionally, this project required a lot of stretching on the part of the undergraduate groups. They were being asked to perform as graduate students, reaching ahead of their present role as undergraduates. During routine weekly check-ins, Dr. Holmes would ask the students to report their week's progress. One semester the group consistently responded with silence—a situation that commonly arises in active and interactive learning. Dr. Holmes recalled, "They were always participating, but the way that they were participating, with silence, didn't allow for me to give much in return."

In these situations, an educator has the opportunity to use authority to force the desired report out of the reticent group. This achieves a desired product, the report, at the expense of building a stronger class ensemble or helping students to participate more readily in the future. But when we instead consider the students' reticence as a collaborative performance composed of offers, we might instead say that the offer given to these students—a prompt to report—wasn't giving them quite what they needed in order to produce a strong subsequent offer in the form of a useful summary of their research week.

Dr. Holmes's response was to try a more generous offer: she asked the students to instead tell her "two truths and a lie" about what had happened that week (Table 2). She explained, "It's about being playful and saying something. Say anything. I don't care what you say, I want you to speak to me. Because in the absence of us interacting with words, there's nothing for me to work with."

Given this novel prompt, the students were able to participate and make a counteroffer—one that Dr. Holmes was indeed able to work with. "And when they do," she explained, "it's wonderful. You're excited. You're like, 'Oh my god! That's such a great lie! That was so interesting! How did you come up with that? What were you thinking? Who are you?'" Making a more generous offer helped Dr. Holmes to receive more generous offers in return, ones that not only (with a bit of discussion) provide a pathway for the functional group updates required in a long-term collaborative project, but provided an opportunity for Dr. Holmes to have more interesting interactions with her students as a research ensemble. And the reticent group found it easier, after that interaction, to participate with more generous offers.

Dr. Holmes associates the change in her students' interactions to the reduction of pressure to provide truth in her second offer. "People get so stuck in the truth. People shut up when they think they have to say something that they experience as true." We suspect that the novelty and playfulness of her offer also increased its generosity—the opportunity to think creatively about a lie makes for a more interesting experience than the straightforward cognitive labor of reporting upon one's week of work. At their best, generous offers make improvisation easy by simultaneously reducing the risk and increasing the cognitive reward of interaction.

Spontaneity

A notable quality of Dr. Holmes' adaptation of "two truths and a lie" is that not only was it a rather spontaneous offer on her part, it opened the door for satisfying spontaneity and playfulness among her undergraduate participants and herself. Spontaneity is, of course, the signature feature of improvisation in general [2,3,6]. It is also a key feature of most active learning pedagogies, particularly those that involve small-group collaboration. Within small groups, students interact and solve problems in an unscripted manner that follows a path dictated by the ensemble: the strengths, style, and personality brought to the table by student participants, and the kinds of offers they are able to make and build upon with one another.

Though spontaneity is a strength of active learning, it also entails some loss of predictability—a significant source of anxiety for many educators, particularly those in engineering or STEM in general [1,11]. Loss of classroom control weighs heavily on the minds of instructors making a transition from lecture to active learning. Yet somewhat ironically, opening the door for a bit of spontaneity in a STEM classroom can be one of the easiest ways for an educator to test the waters of classroom improvisation. When we asked Dr. Susan Walsh about ways to adapt improv methods and activities to traditional STEM classrooms, she suggested an activity that she does frequently in large-lecture biology classes: she pauses her lecture to prompt her class to stand up and act out the motion of a given bit of lesson content along with her. "I take these abstract concepts and make them visual for the students" (Table 2).

"They are not necessarily going to remember that picture of the lipid bilayer that you put up, but [after taking a moment to act as lipids] they will know the difference between saturated, non-saturated; they are pushing each other around." Thus allowing students a moment to react creatively to a scientific concept helps them to make better cognitive connections, and it adds a negligible amount of time and unpredictability to a large lecture.

When considering spontaneity as a part of an educational experience, it's important to remember that students themselves will naturally make spontaneous offers if given an opportunity, provided the environment is sufficiently safe and supportive. Often we need merely to provide a good structure, and students will pleasantly surprise us and one another. Consider an example from Dr. Regina Griewe Jackson's class. She'd prepared an opportunity for students to interact through a Canvas discussion board (Table 2). Prior to class, students had completed a survey with basic information such as major, hobbies, and outlook on math education. Dr. Jackson prompted students to interact on the discussion board to try to find other students with whom they had something in common from the survey. This introductory offer was generous, in that students need merely choose an offer from a limited set, which is easier than coming up with one compatible fact out of an infinite number of possibilities. Yet the students still got to choose what they wanted to share as an offer to connect with others.

In one group, a student offered her major and class standing: "I'm a nursing major, and I'm a freshman. But I may not be for long." In response, another student offered, "You might want to be careful. If you want to switch, switch quickly. I'm a senior and switched, and realized I still have at least a year to go." This remark prompted a lively thread of discussion as many students joined in to offer and accept advice. In this way, students helped each other and built a strong community before even meeting in class.

Rules and structure

Improv performance's strong association with spontaneity obscures an important facet of improvisational methods: in order to give players a good situation for constructive spontaneity, all players agree *a priori* to a set of rules [2,4,5]. The rules that underlie improvised performances provide a guide and safety net for players. They also provide liberating constraints that promote creativity. It has been noted that rules are central to successful improv performance, and indeed, performers need some structure to react to if they are to be spontaneously creative together [5]. Rules in dramatic and comedic improv can take the form of practical tenets of action that help a scene to thrive; for example, improv comedians are told to never start a scene using a question as an initial offer [2]. But just as frequently, the rules for improv exercises sound quite a lot like the rules for children's games [4]. (Many very productive and educational improv exercises *are* children's games.)

Take the improv activity, “Zip, Zap, Zop” (Table 2). This simple game, performed as a group in a circle, is common among children and students of theatre alike. The essential rules are that students pass energy (and turns) by pointing to another and yelling “Zip”, “Zap”, and “Zop” in sequence. As the players gain momentum an inevitable mistake occurs. Everybody applauds the mistake, and the game starts over. The rules provide a structure to keep action quick and easy between players. This frees them to focus on other players’ actions and play creatively while passing offers of turns.

Though playing a circle game seems incongruous with a STEM education class, several of the educators whom we interviewed independently reported incorporating this activity into their teaching to great effect. Our discussion with Mr. Taylor about his choice suggested some of the reasons for the game’s portability: the game, even with a preface and debrief, took only about fifteen minutes. It raised the temperature of the room, provided a safe and fun means for students to interact and become accustomed to making eye contact with one another, underscored nonverbal communication skills such as deliberateness of action and gesture, and the joyful applause at mistakes went a long way toward establishing a safe environment for group expression and learning.

Mr. Taylor told us that he finds an explicit declaration of rules to be particularly helpful when presenting improv activities to engineers and others with STEM backgrounds, in part because the students are often used to activities that are structured. The declaration of rules helps his students to feel comfortable and safe in participating. “That’s a way of saying, ‘Here’s what happens when it goes right. Here’s what happens when it goes wrong,” he told us. “It does a nice job of opening this idea of transparency in the classroom”. We would add that it seems to provide a framework that makes it easy to act spontaneously—the same students who might find it difficult to introduce themselves to one another unprompted might quickly find themselves pointing, laughing, hamming up the turn-passing actions, and applauding others without social difficulty.

Many of our interviewees also hinted that an educator who is comfortable improvising often has a structure set out for himself. For example, Mr. Taylor teaches STEM students to become better research storytellers by finding the arc of their work’s story and improvising around it. This is a technique that he himself uses to lead discussions, so that when spontaneous tangents arise, he can mentally check back in with his intended story arc to guide discussions back to content. “At the beginning of every class that I teach, I have an outline. I write it down on the board,” he explained. “Then having that minute to break, and say, ‘Where are we in our arc of the day?’” This structure helps him to allow his students to follow interesting threads of discussion, yet provides a tool for him to bring the discussion back to its intended arc without discouraging students: “We haven’t done anything wrong; this discussion isn’t bad”.

We feel that examining the rules and structure that underlie improv methods is an extremely promising area of transfer between improvisation methods and the active learning classroom. Showing students frameworks that can scaffold their successful work together as a group can make it both easier and less frustrating to perform well together. Knowing that there can be an order that underlies students’ learning and spontaneity in groups may do much to allay the specter of chaos for teachers who are new to active learning.

Acceptance and building

Perhaps the most universal rule that unites all forms of dramatic improvisation performance is that all offers must be accepted and built upon with new offers. Successful improvisers must only move forward and up and together [2–4]. When offers are "blocked"—that is, ignored, negated or rejected—it creates a nearly impossible real-time barrier for additional offers. Consider a story told by Del Close about being blocked by Joan Rivers [2,12]. Rivers initiated their collaborative scene by proclaiming, "I want a divorce!"

Close offered, "But honey, what about the kids?"

And Rivers blocked: "We don't have any kids!"

Rivers got herself a laugh from the audience, but stopped the scene dead in its tracks. She'd made it difficult and high-pressure for Close to make a next offer. Perhaps worse, she'd damaged the relationship and trust that help performance ensembles to work over time. Close avoided performing with Rivers after that fateful block.

We can easily see the effects of blocking in our everyday lives. Talking over others, ignoring them, or correcting them in a way that causes them to publicly lose face certainly has a similar effect on real life performances as Joan Rivers' block did on Del Close—blocks make it harder for other players to make new offers, now and in the future. Destructive blocking often occurs in classrooms, especially in group learning situations. Among educators, a frequently bemoaned archetype is the student who seizes control of the group, negates his teammates' contributions, and poisons collaborative interactions before they can take root.

A culture of accepting offers is as important to an ensemble of active learners as it is to an ensemble of performers. Yet, particularly in engineering, there is a confounding factor—we value correctness, often without regard for the means. A student who believes herself to be reliably correct may feel justified in blocking the contributions of others in a team ensemble, or at very least, not acknowledging them. Similarly, a team may feel itself justified in blocking the offers of a member whose contributions they deem less likely to lead rapidly to a correct answer. Indeed, many educators squirm at the idea of accepting all offers, because it seems to imply that the instructor must implicitly endorse offers—answers, solutions, theories, comments—that they know to be incorrect.

Many of our interviewees acknowledged the potential conflict between accepting all offers and valuing correctness; yet none found these values to be mutually exclusive in practice. The educators we interviewed had each found ways to accept and build upon students' offers without endorsing incorrectness, often in ways that were extremely compatible with the way that science and engineering are performed by professionals.

For example, Dr. Nicholas Gross recounted a recent active learning experience he'd facilitated among novice science educators, in exploration of the practice of science. The scientific content of the class concerned the physics of pendulums. As we know, one can easily look up "correct" formulas for a single-mass pendulums; but rather than start there, Dr. Gross opened the activity by asking participants for guesses about what *might* affect the motion of a pendulum. " 'What do you think, what are the possibilities that could affect, what are the possible properties of a pendulum that could affect its period?' " Dr. Gross prompted. Pendulum length, weight, material, even color; "Anything anybody said got put up on the board. No matter how crazy it was, or ridiculous."

Following the broad acceptance of suggestions, Dr. Gross led a discussion about how one might set up experiments to test these guesses. Then groups were prompted to choose a guess to test. Within the class, each group improvised a test setup from available materials and conducted experiments. Dr. Gross talked to groups individually during this time and asked them guiding questions to help them think through difficulties and stoppages. And finally, each group reported their findings to the whole class. The students, as a group, discussed these findings in light of Galileo's pronouncements on the pendulum—some of which we now consider correct, some of which we do not—and evaluated whether their findings were in agreement.

We can easily recognize this activity's authenticity to research professions. It is a model of the process of scientific inquiry. It is also highly improvisatory, and offered many opportunities to accept and build upon offers as a group—formally during the brainstorming/hypothesis step, and more informally within the groups' ensemble-based experimental planning. Yet the class ensemble did indeed learn "correct" things about pendulums, along with firsthand knowledge of the process by which we generate knowledge through empirical means.

Dr. Gross's experience illustrates several themes that came up among our interviewees concerning accepting and building on offers in a STEM paradigm.

1. A generous initial offer from the instructor.

An offer that serves only to test or evaluate members of an ensemble is rarely a generous offer. Generous offers help the ensemble to succeed together. When offering prompts for active learning, a certain generosity helps the activity to be educational and satisfying. As Dr. Gross remarked, "If your goal is 'I want this set of undergraduate engineering majors to understand not only things about pendulums, but also how we develop relationships, the mathematical relationships between the variables, and how we verify them', then it becomes a lot harder to fail." Generous offers help student ensembles, particularly new ensembles, to focus on building processes and making educational guesses and checks, rather than focusing on being opaquely correct in front of others. This potential for transparent, process-focused learning is one of the strengths of small-group learning paradigms, and an early and ungenerous focus on correctness reduces the pedagogy's potential. It makes sense to make the opening offer easy, fun, and low-pressure such that a student succeeds by authentically contributing to group knowledge. Evaluative tasks or public demonstrations of correctness can come later in the learning activity.

2. Withholding judgment.

A related concept from improvisatory performance is *withholding judgment*. A beginner improv performer with his own performance at stake may be inclined to pick at or block other ensemble members' suggestions or offers. But a good ensemble member soon learns that the best time for evaluation and pruning is not during improv exercises and games, nor during preparation times when each member shares ideas and offers with the group. At these times, withholding judgment and showing appreciation coaxes others to bring increasingly interesting offers to the group. In this way, withholding judgment is identical to best practices for brainstorming sessions, which allow for a constructive and creative time of free sharing and building upon each other's ideas. Indeed, one of the most-reported areas of cross-pollination between improv methods and professional practice has been the use of improv techniques to complement brainstorming[13–15].

Dr. Walsh recounted the example of guiding her students in an improv-based method to brainstorm possible experiments for their senior projects (Table 2). During the opening discussions, students are encouraged to put all ideas for experiments on the board, no matter how crazy—and they do. Practical, whimsical, original and derivative; all ideas are accepted without critique. Dr. Walsh explained, "If we start negating offers, the group participation decreases."

When the board has been filled and all offers accepted, Dr. Walsh and the students review them. As an ensemble they consider the list in terms of pragmatic criteria like costs and time. Together they winnow the list down to a smaller set of promising experiments from which to choose.

3. Making knowledge, decisions, and risks a property of the ensemble rather than the individual.
When Dr. Walsh's student groups select experiments from that winnowed list, they are encouraged to form groups according to which experiments most interest them. The list of experiments has thus become the property of the ensemble rather than individuals. Dr. Gross similarly transfers the collected experiment ideas from the realm of individual groups to the realm of shared knowledge, encouraging students to take up any experiment that they're interested in trying whether they brought it to the group or not. "When you go to a more student-driven design, which treats the classroom as a community," he commented, "then the community can succeed."

In both cases, no individual was judged for his or her offered content, and all offers were accepted. The ensemble itself, led by the instructor, made selections and judgments from this shared material. Certainly evaluation happened in both experiment selection activities; yet it became a matter of ensembles choosing agreeing upon a shared action, rather than individuals being judged for their offers.

One of the many reasons that ensemble learning offers such potential is that being part of a group, if that group is interacting effectively as an ensemble, can reduce some of the risks and pressures associated with individual performances. Ensemble cohesion helps a student to contribute, to evaluate without taking the matter personally, and to communicate without fear of judgment. The safety of an ensemble is one way of explaining why clicker questions and full-class polling have become such successful classroom implementations. As Dr. Jackson told us, students who have trouble standing up to present in her classroom generally participate enthusiastically in clicker items or thumbs up/thumbs down questions. "As long as they think it's anonymous, they'll interact."

Celebrate mistakes, fail cheerfully

Dr. Holmes recounted an example of intentionally scaffolding ensemble ownership through a simple game called "Yaaay!" (Table 2). In this game, one player in a circle makes an offer about another player: “You’re from Toronto”. The addressed player comments on the veracity: “No, I’m from San Diego!” And in Dr. Holmes’ version of this game, the correct response is that all members joyfully throw their hands in the air and reply, “Yaaay! We were wrong!” And play continues. Dr. Holmes explained that she likes this as an introductory game because it underscores the notion that the action of any individual is also the action of the ensemble, and it can be a joyful occasion when an ensemble fails cheerfully together.

The role of mistakes and failure are a major theme of improv theatre’s literature-of-practice, which acknowledges that since improv is unscripted and experimental, failures must be treated cheerfully. They should be used as offers and launching pads for further creativity, and used as an opportunity to practice buoyance and ensemble unity [3,13]. Indeed, many improv games enshrine a celebration of mistakes within their rules of conduct.

“I think that once that feel of the group happens,” said Mr. Taylor of these celebrated mistakes, “then people are really a lot more eager to participate. There’s a noticeable change in the dynamic of the group.” Mr. Taylor made special note of the effect of applauding mistakes in his game of “Zip, Zap, Zop”/ “Car, Bus, Truck” (Table 2). “I always notice the same thing happen. The first time, everybody claps and it’s weird. You *never* applaud, right? And then the second time, it’s a little more natural. And then after that, for *everything,* people are applauding. ‘You did great!’ or ‘You messed up!’ ‘Somebody said anything—we’re going to clap.’” Dr. Walsh noted a related effect that the game has on her own students: it brings them together. “They play a silly game, and the group makes mistakes. It is not laughing *at* the people; it is laughing *with* the group about the silly mistake.”

Like the related concept of accepting all offers, celebrating mistakes may seem initially at odds with our value as engineers for demonstrations of correctness. Yet identifying mistakes and using them as an opportunity to refine our individual and shared knowledge is a very important part of engineering research and practice.

Finding ways to normalize mistakes and failures, and make them safe to perform in public, enables a number of learning enhancements. Foremost, it allows us a much less complicated means of understanding what our students are learning and what they find challenging. But perhaps more importantly, when mistakes seem safe, it enables students to practice seeing mistakes and feedback as helpful and nonthreatening. A learner’s constructive attitude toward mistakes is a major component of current pedagogical concerns such as growth mindset, mastery-based learning motivation, reflection and resiliency [16–19]. Improvisatory education methods provide us with a very promising strategy toward scaffolding a value for mistakes in the learning process.

The ensemble

Perhaps the most valuable concept that we might import from improvisatory theatre is the explicit acknowledgment of the class body as an ensemble[2,4]. Within a performing group, there is an understanding that each ensemble is a unique entity that is dependent upon the contributions of individuals (their particular set of experiences, knowledge, and strengths) and also a function of what those individuals are able to build with one another. The members of ensembles all bring unique offers to create a collaborative whole. As Dr. Holmes suggested, "Go back to the jazz ensemble. They're playing in the same key. They don't sound alike. The instruments are very different."

"What you're working to do is create an environment of the group, where people can optimize themselves. Where what they are giving is used by the group. So when they're separate, not functioning as a cohesive ensemble, whatever's being offered cancels each other's contribution out, rather than helping the group out. So the question becomes: how do we give what we have to give, and have that benefit the group?"

It is important to remember that while an instructor may have ultimate responsibility and increased authority, the instructor is still part of the ensemble. A member with a particular role, certainly; but no less a unique individual who can contribute with generosity and vulnerability, who can create anew with student collaborators, and who can have fun and learn in the process.

Misconceptions

When we asked Dr. Walsh what faculty should know about improv methods, she provided us with a succinct list of misconceptions that might prevent faculty from seeing the potential for improvising in STEM. Dr. Holmes offered one more. These misconceptions were strong themes across our interviews. Each STEM educator we interviewed touched upon one or more of these misconceptions, whether they'd had extensive improv training or no improv training whatsoever. In support of translating and adapting improv methods and terminology for use in engineering classrooms, we'd be remiss if we didn't address some major misconceptions that might prevent an instructor from wanting to consider improv techniques as tools for teaching in engineering classrooms.

Misconception 1: The purpose of improv is to entertain.
Dr. Walsh and Dr. Jackson both noted their roles as entertainers in their large-lecture classes, and discussed how improvised activities helped them to keep student attention. Yet improv methods in learning can't be dismissed as purely an entertainment tactic any more easily than active learning itself. As Dr. Raquell Holmes explained, "That improvisation is fun is a *bonus!* Right? Yaay! How wonderful is that! But this stuff is hard work! Because you're asking people to take risks." Dr. Holmes statement echoes that of other educators who study improv experiences as a vehicle for learning and community development—improvisation methods are tools that can do far more than create spontaneous comedy.

Misconception 2: Embracing improv implies endorsing incorrect answers and procedures.
Time and again, our interviewers stressed that improv didn't excuse us from our role as guides, nor did an improvisatory approach to teaching STEM conflict with our roles as assessors and evaluators. Rather, classroom improv shifts the need to be correct until later in the discovery process, and requires that an educator make strategic choices about when and how an ensemble and individuals demonstrate correctness.

Table 2: Classroom improvisation activities referenced by our interviewees.

Activity	Description	Outcome
Two truths and a lie	When students stay quiet rather than answering an oral question, the instructor explicitly asks for *two truths and a lie*.	It removes the fear of making a mistake, and students will be more willing to contribute with an answer.
Act out a concept	The instructor and/or students stand up and make physical gestures that are characteristic of the concept of interest. It can be followed by acting out a contrasting concept.	It awakens the class, stimulates the cognition, and has the potential to providing a memory that is not available in the textbook.
Icebreaker	Ask questions that will promote the voluntary exchange of either personal information or random words. For example: hobbies, interest in the class, expectations, prior experience, name and a color, name and mood, two feelings, etc. Can be via a web-board, or in class (virtual or physical).	Helps students start creating groups for the in class assignments; helps the group pay attention to each individual.
"Zip, Zap, Zop" (or "*Car, Bus, Truck"* for groups with individuals whose English is a second language)	All participants stand in a circle. One participant holds a "bolt of energy". By making eye contact with another participant, the energy is passed (with an explicit gesture) by saying 'Zip'. The new holder of the energy will pass it with 'Zap', and the next with 'Zop'. The exchange should happen quickly. The cycle continues until there is a mistake. The whole group must loudly celebrate the mistake (applause, or "boing!"), then the game can be restarted. http://www.utexas.edu/cofa/dbi/node/29	Enhances focus, the use of eye contact (sensory awareness and perception) and improvisation. The celebration of mistakes promotes ensemble building.
Brainstorming	Can be used for a concept or a project. The group contributes suggestions to the topic. First, all ideas are accepted and collected on the board. After, the group discusses, eliminates items, and chooses directions to pursue. The ideas belong to the group, and do not need to be pursued by the original contributor.	Helps the group 'discover' the concept of interest, or experiments and projects that will be of interest to the group. Improves engagement and helps build ensemble.
Anonymous questions	For binary/multiple choice answers. Use clicker, ask for thumbs up/down, color cards.	Students that are reluctant to speak up or stand up in front of the class are more willing to participate. Provides the instructor instantaneous feedback on content comprehension.
Yaaay!!!	One participant makes an offer to another: "You're from Toronto", and the second comments on the veracity: 'No, I'm from San Diego!". If the answer was incorrect, the group celebrates "Yaaay! We are wrong!"	Icebreaker. Promotes ensemble building, by underscoring that the action of an individual is also the action of the ensemble.

Misconception 3: Improv requires no planning.
Each of our educators stressed that creating educational opportunities for improvisation did indeed require planning, and plenty of it. Our educators certainly talked about planning improv much like any other class activity, down to the class time they were willing to spend on a game and a follow-up discussion. But equally often, the planning looked different than the kind of step-by-step planning that an educator uses when she expects to be the sole source of teaching and knowledge in a classroom. Many of the educators discussed going into the class with a strong conceptual idea of how the class should play out—in some cases, a "story arc" for content exploration or for students' reactions, or else a set endpoint to pursue, with the path negotiated and traversed spontaneously as an ensemble.

Misconception 4: Improv takes a lot of time.
As Dr. Walsh described, improv can be as fast as asking students to act out a concept from their seats. As Dr. Jackson showed in a complementary example from her own classroom, active improv-style learning can save time by helping students to understand difficult concepts more quickly; and as Dr. Holmes demonstrated, sometimes using improv to reframe a required activity such as a weekly progress report can help that activity to proceed more efficiently and effectively. While it is only practical to recognize that most unscripted and interactive learning (i.e. most active learning pedagogies) generally do take more time than simply lecturing, a strategic implementation can ensure that this time is paid back in quality of learning.

Building, forward and up, together

Viewing active learning within the framework of improv helps us to more clearly articulate further questions that are worthy of exploration among educators and improvisers alike. Three sets of questions that seem particularly useful are:

1. How does an educator improvise? How may we use improv methods to perform better as educators?
In this paper, we have focused on the experiences of faculty who have facilitated improvisatory experiences for students. Over the course of our interviews, we also heard a wealth of stories about times that the educators, themselves, improvised. A common theme among these educators was that frequently they knowingly and intentionally left room for uncertainty and unscripted performance in their teaching. This is quite a far cry from the controlled and scripted lecture format that is still the most common format for engineering coursework. Better understanding of both the learning process and the performance practices of educators who embrace unscripted teaching might offer us a wealth of insight toward lighting a path for other faculty who are transitioning from lecture to active formats.

2. How are improv exercises useful toward inclusion in engineering? How may improv techniques be adapted to ensure inclusiveness?
Improv-based education has long been used as a vehicle to empower the disenfranchised, and promote an ensemble spirit among diverse groups[20]. It has also been used successfully among international and ESL students, including those in STEM disciplines[21–23]. Similarly, improv has promise as a method of breaking down barriers and promoting inclusion in engineering.

For all their potential for inclusion, improv activities are not a one-size-fits-all pedagogy. A shrewd facilitator must often adapt an activity to ensure that a diverse ensemble can participate and offer. A creative example from our interviews was Mr. Taylor's innovation on the classic "Zip, Zap, Zop" format. In response to international students' difficulties with the game's three phonetically similar keywords, he changed the activity to suit his class ("Car, Bus, Truck"). As improv is adapted for engineering pedagogy, it must also align with universal design if it is to realize its great potential as a vehicle for inclusive teaching.

3. How may we better understand ensemble in classrooms? How may we be better ensemble builders?

If a theatrical director is adept at helping a group of individual performers to find group cohesion, trust, creativity, and a unique but shared voice, that director is said to be a good "ensemble builder". Implicitly, an educator who engages in interactive learning should want to be a good ensemble builder, as well. We have much to learn about what facilitation practices help ensembles to grow. We also have much to consider regarding our own dual roles as ensemble builders and ensemble members.

This paper provided a foundation in improv principles, illustrated by STEM educators in active learning settings. In the process, it underscored that improv among our students has a place in engineering education. Yet improvisatory learning experiences are certainly not novel in engineering curricula; improv structures and principles can easily be seen in the implementation of any lab or capstone class. Thus the primary reason to consider the principles of improv is not their novelty, but their value as a clarifying framework. Improv throws into focus the aspects of unscripted collaborative learning that we often treat as ineffable: social, collaborative contribution. By more carefully considering improv methods in our activities, we have a better language to consider what is happening in our interactions. We can make use of framework that has been used by theatre educators and professionals for decades or even centuries in order to guide ensembles toward constructive collaboration. And thus we can make engineering education an experience that better prepares our students for their professional roles as collaborators, prepared to build creatively and successfully with one another.

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