The Ballet Model in Engineering Classes – What Works, What Doesn't, and What's New

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Abstract - **Six different engineering courses were taught using aspects of the classical ballet instruction model in organization, teaching methods, and learning strategies. There was a strong focus on performance. The courses spanned sophomore to senior levels. Some aspects of the ballet model worked well: setting rules for the Sacred Space for learning, the beginning activity ("stretch"), the overall organization of the class session, communicating the known ideal, including historical background, and using demonstrations. Some aspects did not work (thus far): exams are not yet performances on stage, little practice or rehearsal occurs, little competition between students occurs, asking students questions in class is uncomfortable, and many students do not want to be in class. New ideas presented include "casting" for exams and highlighting the role of repetition in learning. It was deemed worthwhile to apply the performing arts model to foster increased learning during engineering class.**

Index Terms – Ballet class, Engineering class, Exam, Performance, Sacred space for learning.

INTRODUCTION

The objective of classical ballet class is for students to learn and improve technique with the goal of expertise demonstrated in performance. The class is physical and the results of the student's efforts are evident. Students are immediately accountable for their actions. The class is extremely challenging. The focus on performance is understood and anticipated. Traditional engineering classes have taken a much different approach. The goal is the transmission of information. Most learning occurs during homework or studying apart from class. The class is passive with students resting in chairs as they take notes or, as is becoming increasingly more common, watch PowerPoint slide presentations. There is little accountability on the students' part. Class is not particularly challenging or engaging. This can be because either the students are not provided with sufficient challenges, or they do not rise to the challenges presented. The focus of engineering class is on getting through the material in the time allotted. Ballet class embodies striving for excellence; engineering class embodies striving for covering topics. Table I summarizes the characteristics and goals of the two approaches.

TABLE I
CLASSICAL BALLET AND ENGINEERING CLASSES

Class	Characteristics	Goal
Ballet	Physical, Challenging, Accountable	Expertise demonstrated in performance on stage
Engineering	Passive, Easy, Unaccountable	Present information & topics

The ballet model works to produce competent, *trained* professional dancers. The traditional engineering model has worked to produce competent engineering professionals in the past; however, it is doubtful this model will continue to work in the age of greatly improved technology, ever-increasing amounts of material to cover, and a student population increasingly uncomfortable with the "straight lecture" class format. Engineering education needs to change.

It is valuable to take many of the elements of the structure and practice of classical ballet class and apply it to an engineering class setting [1]. We believe this leads to increased learning in class, more self-confidence and mastery by the students, and a clearer sense of why they are in class. The paper that follows is descriptive in nature. Our purpose here is to present these ideas, and our experiences, as possible new avenues for engineering education. The courses where we applied our ballet model spanned sophomore, junior, and senior levels (Table II). Each course varied in how much the ballet model was applied in approach and in practice.

TABLE II
ENGINEERING COURSES TAUGHT USING THE CLASSICAL BALLET MODEL

Year	Course
Sophomore	Introduction to Materials Engineering Materials Engineering Laboratory
Junior	Mechanical Behavior & Properties of Materials Mechanical Behavior & Properties Laboratory Composite Materials Ceramic Materials
Senior	Materials Selection in Mechanical Design

WHAT WORKS

Several effective methods transferred directly from classical ballet class to each of the engineering classes taught using the ballet model. It is not so surprising that these worked to improve the learning environment in class and lab since they have much in common with active and problem-based

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learning techniques [2-9]. However, the ballet model is somewhat different from current active learning models in both philosophy and practice.

I. Sacred Space for Learning

A professional in the performing arts – classical ballet, symphony orchestra, opera – knows that the theater is a *sacred space*. So much history, majesty, and art have occurred in the theater that the space itself deserves a high level of respect and even reverence. It does not matter if it is La Scala, in Milan, The Academy of Music, in Philadelphia, or the small hometown theater around the corner, every theater is a sacred space that carries with it an entire set of appropriate behavior. There are things you do, and things you do not do in the theater. It is a place of time-honored rules. The best classical ballet instructors bring the sacred space ethic into the ballet studio and with that a respect for the art. There are rigid, non-negotiable rules on how to dress, enter class, act in class, address the teacher, and leave class. The rules create the proper atmosphere for learning. The rules free the instructor and the students to concentrate on the teaching and learning aspects of the class. The rules help, instead of hinder, the learning process; they are an integral part of ballet class.

We applied the sacred space ethic successfully to each engineering class taught using the ballet model. The first day of class, every student was given a Sacred Space-Learning card (Figure 1). The card included a series of rules each member of the class, instructor included, was expected to follow. Each rule was directed at achieving the most effective teaching and learning environment possible. For example, everyone had to be on time to class; latecomers were not admitted. When the door closed to signal the start of class, students agreed they could not enter. In a typical class of 30 students, it did not take long before *all* of the students were on time to class or lab. In previous offerings of the same class or lab, perhaps 10-25% of the class was late. It is much more effective to begin class on time and with all in attendance. It sets a professional tone for the session. As a way to bring this professional atmosphere to what the students wore, we required students to remove their hats and not wear flip-flops or other kind of casual sandals. Informal student opinions indicated that they took the class more seriously when they followed this rule. No class member was permitted to eat or drink during class. This would shift focus away from the material being learned in class. Food can be a powerful distraction. As a final example from the Sacred Space-Learning card, we asked students to pack up their belongings only after the formal Class Closing. This made the last few minutes of class truly effective instead of having the noise and disruption of various students packing up their things while the class was still ongoing.

Possibly the most difficult sacred space rule for students to follow was to *attempt all questions posed*. The all-to-common response "I don't know" was not allowed. Students had to take an educated guess, to make an attempt at an answer, instead of "hiding" or simply deflecting the question

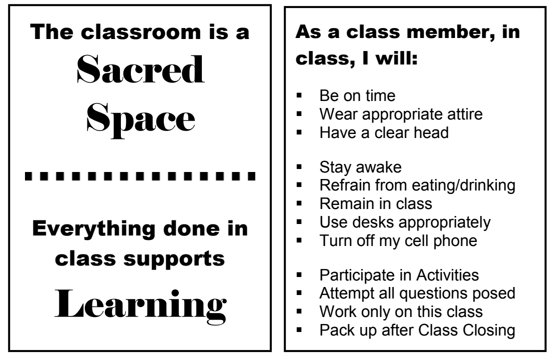

FIGURE 1
SACRED SPACE – LEARNING CARD.

with "I don't know". We took this directly from the ballet model. When a ballet instructor asks a student to perform a certain combination of steps, the student then does his or her best to do it, and the teacher corrects what the student has done. Saying, "I can't" is not allowed because it will not produce the desired effect of improvement. It is perfectly fine to try and fail in class. Class is safe. The most important part is the attempt. When this on-the-spot performance was applied to engineering classes with a question asked of a particular student, the students were automatically engaged with their attempted answer. In addition, they were accountable to the class and to the instructor – a vital part of engineering education missing in most classes. Correct answers were quickly taken as "gospel" and the class session moved on. Incorrect answers were slightly corrected or refocused and then posed to another student for help. As in ballet class, it was perfectly fine to try and fail, the most important part was the attempt. Answering questions was a challenge for many students; however, most students in major-specific classes at the junior and senior level rose to meet this challenge as the course progressed.

II. Stretch

Most classical ballet classes begin with some basic stretching exercises that prepare the student's bodies for what is to follow in class. This beginning activity serves the dual purposes of getting the students immediately engaged in the class with something useful and setting the professional tone of the class (e.g., no talking, concentration on the stretching exercises). Engineering classes can begin the same way. The first thing that happened in each engineering class taught using the ballet model was a beginning activity called the *stretch*. The engineering stretches were brief activities based on what was covered previously in the class or what was to come in the current class session. Each was doable in five minutes. They were meant to be done without the aid of notes, text, or references – the answers came from what was in the student's heads. The stretches were completely for the student's benefit; they were not collected or evaluated. They acted as a barometer for how prepared the students were for the coming class session. They were extremely successful in getting the students on task immediately.

III. Class Session Organization

All classical ballet classes are structured in the same way. The common organization helps students learn the material because they can rely on the structure to be a constant. The engineering classes taught using the classical ballet model were organized somewhat like a ballet class [1]. A companion organization page captured what the instructor was going to cover and emphasize in that session. Preparation for a given class session involved filing out and addressing various parts of the organization page. All class sessions were based around the Activity and Activity Critique. However, other parts were equally important including the Demonstration, Historical Context, and Engineering Links. Having a common structure to the class sessions meant that students expected to work on an Activity during class to gain facility with the new topics and concepts presented. They could also rely on the constant structure to aid learning.

IV. Communicating the Known Ideal

Classical ballet students know what they are going after in class. They want to attain a certain line, perform triple pirouettes, or dance that particular variation, for example. The best ballet instructors communicate these known ideals to their students by demonstration and explanation. The explanations in ballet class are as important as the demonstrations because they give the vital basis of movement that enables students to see how it can be properly executed. Traditional engineering classes are designed to transmit information – usually a lot of it. Many times the students are not really sure why they are learning a certain topic. One of the true strengths of the ballet model was the focus on *why* certain topics are covered and *how* they are used in engineering applications. Following ballet, these were communicated to the students through demonstration and explanation. Providing the proper context for the material the students are covering is one of the characteristics of effective teaching and learning methods. Providing the known ideal in engineering classes addressed part of the context issue.

V. Historical Background

Context is not only important in engineering applications but in the history of engineering practice and discovery. An awareness of what has come before can inspire students to a high level of achievement in a given course. In addition, simple ideas and concepts can be learned by nearly 100% of the class with the most basic connection to history: people. In Materials Engineering, for example, the phases of steel can be difficult to remember on first exposure in the Introductory Materials Engineering course. However, nearly all of the students learned them – including the proper spelling – after connecting each with their discoverer: austenite (after W. Roberts-Austen), martensite (after A. Martens) and bainite (after E. Bain). More profound concepts can be mastered with the clear connections to the original engineering and scientific pioneers. This was a challenge to include in the limited time of a given class session. The beneficial effects often proved worthwhile with greater student involvement and curiosity.

VI. Demonstrations

Ballet class works because the instructor can successfully demonstrate the steps, positions, and combinations. The amount of demonstration varies with instructors – it does not have to be the full-out version of the dance steps. It is the intent and line of the teacher that become most clearly demonstrated and communicated to the ballet students often with subtle, but expert, movements.

Engineering class can benefit a great deal from this focus on demonstration. This is well known in certain courses and for certain topics; however, it is incumbent on engineering instructors to apply the demonstration mindset to *each* class session. The challenge is to create and use demonstrations that help communicate each topic and concept presented. As with ballet class, the engineering demonstrations need not be elaborate, expensive, or greatly time consuming. For example, ripping newspaper in one direction (rips straight) and at ninety degrees (will not rip straight) quickly demonstrates anisotropic mechanical behavior. "Simple" demonstrations can be extremely powerful for helping students grasp difficult concepts.

WHAT DOESN'T WORK (YET)

The classical ballet model cannot be seamlessly applied to engineering classes. There were several instances in the suite of courses taught with the ballet model where performing arts and engineering did not mesh.

I. Exams Are Not Performances On Stage

The focus of classical ballet is excellence demonstrated in performance on stage. The performance represents the opportunity to utilize all the practiced skills from class. The experience of performing can be exciting, rewarding (depending on preparedness), and frightening. Ballet students look forward to performance. They continually strive for excellence in class to help their performances. This is one of the main things that keeps ballet students coming to class. Performance is high pressure and should be – one shot is all you get; better know your stuff. There are no excuses, no negotiating. Even with this pressure, dancers will look forward to the next performance almost immediately after leaving the stage of the current one. Could we achieve this with engineering exams?

The focus of most engineering students is their performance on exams. Exams are still the way the vast majority of engineering students get to demonstrate that they have mastered the material presented in a course. There is a similar high pressure associated with the exam as with the on-stage performance, but engineering students routinely dread exams. It was our hope to bring the excitement and anticipation of a performance to engineering exams. However, nearly all the students in the classes taught with the ballet model were far from the ideal of viewing an exam as such. Engineering exams were still something to be reviled, the process of taking them was mostly painful, and students were rarely happy or satisfied with their performance immediately following the exam. They were simply happy it was over. The striving for excellence is not yet present in engineering class. This topic remains a challenge for our model. We present a few strategies later in the paper to deal with this shortcoming.

II. Class, Practice, and Rehearsal

In classical ballet, or any performing art, three elements work together to create a high level of performance on stage: class, practice, and rehearsal (Figure 2). Remove any of these, and the on-stage performance suffers. Engineering is not exactly a performing art; it is not done on stage for an audience. However, there are many elements of performance in the engineering profession.

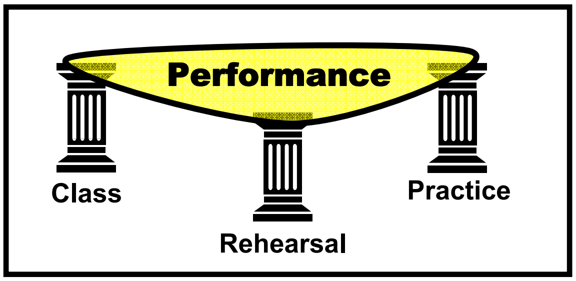

FIGURE 2
THE THREE ELEMENTS OF ON-STAGE PERFORMANCE.

In ballet, *class* is the minimum. If you want to perform classical ballet on stage then you take class regularly. This is true for the beginning to the professional-level dancer. However, class is not enough for performance. There must be an element of *practice* with the ballet steps and movements to get them into the mind and body. Practice occurs outside of class and can range from students working on their own to groups of students working together without an instructor or choreographer. Physical practice has been shown to be an important factor in learning in other fields as well. For example, physical (and mental imagery) practice is key in learning and developing skills in medical surgery [10, 11]. The physical practice approach was also used effectively in getting young children involved with active learning [12]. It appears that practice – especially physical practice – leads to enhanced learning. However, most people do not like to practice, dancers included

Dancers love to *rehearse*. Rehearsal is significantly different from physical or mental imagery practice because it is under the direction and control of an artistic director or choreographer and thus has the key aspect of accountability. Because the students are accountable to the choreographer, they are inspired to do well. The goal of rehearsal is to learn the choreography and become proficient at performing it. Rehearsal is therefore a form of highly structured, repetitive and supervised practice. Dancers will work on the same combinations of steps repeatedly until they become part of their "muscle memory" and can be beautifully performed on stage. What the dancers rehearse is what they will put onto the stage. In summary, class lays the foundation, practice helps make the elements of class more familiar, and rehearsal puts the choreography in the dancer's body and onto the stage. All three are important; however, the key element for performance is rehearsal.

In some ways, the parallel of classical ballet work with engineering education is clear. Our students spend a lot of time in engineering classes, and they practice the application of engineering topics and concepts by solving homework problems. Recognizing the importance of practice in learning, there was a concerted attempt made in the ballet model engineering classes to inspire students to solve homework problem sets on a regular basis (without resorting to collecting and evaluating them). Homework problems were termed "Engineering Links", and these were discussed in class and tied to the concepts and topics presented. Great attempts were made to make more of the problems specific to engineering applications. There were Engineering Links that went with each class session. The disappointing result was that students did not solve the Links on a regular basis. Most of these were attempted and solved immediately before the exam. The result was that the students learned less and performed worse on exams. The small percentage of students who actually worked through the Links scored higher on the exams.

Engineering students do not rehearse. We as engineering instructors expect them to perform well on exams with no element of rehearsal to assist them. There are two practical issues with rehearsal as applied to engineering classes: time and repetition. The most effective rehearsals occur outside of class time, and they need the instructor's direction and control. With the amount of work most students have in college plus the teaching and research duties common to most faculty, it is difficult to find the time both parties can be there to rehearse the material. The strategies used to attempt to rehearse in the courses taught using the ballet model were unsuccessful. It amounted to "extra" time in an already busy schedule for students and faculty. The second issue is the fact that performing arts rehearsal involves learning and repetition of what will occur on stage. If the performance on stage is akin to the engineering exam, then rehearsal in an engineering sense would involve practicing solving problems, explaining concepts, or applying concepts that would be the exam problems themselves. This appears to be counterintuitive to engineering education: practice solving the exam problems and then take the exam? Something needs to change with engineering education because rehearsal is so vital for outstanding performance.

III. Absence of Competition

Everything the students attempt and perform in ballet class is public; engineering class performance by students is private. Even in activity-based classes where engineering students are working on solving problems in small groups, they do not get to see how other groups are addressing the same problems. A truly beneficial aspect of ballet class is the learning that occurs by watching other students perform the movements. It would be beneficial to put this into an engineering class setting. One strategy to accomplish this was to have small groups work on activities on large flip charts. This was not successful because it took too much time, it was difficult to keep bringing multiple large flip charts to class, and the problems were solved in an approximate manner on the large paper. This took students too far out of their comfort zones of solving problems at their desks. Having groups go to the blackboard and work on the activities was always limited by blackboard space and available time.

The public display of ballet steps develops a positive sense and atmosphere of competition in class. The less proficient students truly want to do what the more proficient students are able to do well. The fact that other students are doing it is reinforcing because it means that it is possible and not just something the instructor can demonstrate. In engineering education, we need technology capable of allowing students to publicly perform their activities in small groups or even individually. The competition in class would create an atmosphere of increased motivation and learning.

IV. On-The-Spot Performance

Ballet class can be high stress at times. As mentioned previously, the best ballet instructors will ask certain students to execute a step by themselves because they are having trouble with it. It can be embarrassing when you are the only one dancing in a studio full of dancers. The reason for singling out one person is to help that person improve through teacher's corrections, and because this is a close approximation of performance on stage. The benefits of this individual attention to personal improvement in ballet are immeasurable. A saying in classical ballet class is: "a correction is a gift from the teacher". When ballet students realize that the instructor will single out everyone in class at one time or another, it lessens the stress, but it is still difficult to perform on-the-spot and alone.

This same practice has worked well in major-specific materials engineering classes (junior & senior levels), but only marginally well in our Introductory Materials Engineering class (sophomore level, all engineering majors). In the non-major-specific Introductory course, students do not enjoy being called on to answer questions. It is uncomfortable for them because most of their classes are still pure lecture where they can sit passively while the instructor speaks. Activity-based classes do a lot to break this mold, but many Introductory students find it too stressful to answer a question during a typical class session resorting to "I don't know". This was even the case when it was repeatedly discussed that class time is safe time – they can make mistakes, take educated guesses, and stumble over concepts – the most important part is the attempted answer. It may be such a challenge because students do not want to give a wrong answer, they are afraid of appearing unknowledgeable compared to their classmates, and they are not that invested in this particular course since it is not their major field.

V. I'd Rather Not Be In Class

It is tough to hide in ballet class because what the students are doing is so physical and public. Therefore, it is easy to tell when a ballet student does not want to be in class. This happens in classical ballet classes just as in any class. However, the vast majority of ballet students want to be in class. This is evident when a ballet class session does not get to the student's favorite part; they are disappointed not to be able to do that part of class. This is in stark contrast to the cries of joy when an engineering instructor lets class out early.

For some reason, engineering students can show a high propensity for not wanting to be in class. These students are clearly disinterested in class. They do not want to participate in discussions, work on the activities, or sometimes even take notes during class. Activity-based classes help with this, but simply having activities is not sufficient. The idea that we presented to students in the ballet model engineering classes was that *since* they had come to class they clearly *wanted* to be there (otherwise they would not have come at all). This idea met with only limited success; too many students did not want to be in class. If engineering classes were more physically engaging, it would be much more difficult for students to be this disinterested.

WHAT'S NEW

The experience teaching several engineering courses using the ballet model has led to some new developments. We tried these on a limited scale in select courses. Each idea showed some level of success, but it is too early to tell whether these strategies will be effective.

I. Casting for Exams

In a professional ballet company, not everyone can be a soloist. There must be dancers to make up the support cast, the "corps de ballet". The most technically proficient dancers, the best performers, are cast in the leading roles. They have solo parts and are called upon to perform more technically demanding choreography. They are the featured artists. The best artistic directors and choreographers will cast their dance pieces with the talents of the dancers in mind. A less proficient ballet company member would be uncomfortable cast into a leading role. Similarly, it can be frustrating to dance at a high level only to be cast in the corps. Both of these are contrary to the dancer's proven talents.

Engineering exams can follow the general ideas of casting in the performing arts. We piloted this in two engineering courses with promising initial results. One notable change from performing arts was that instead of the instructor deciding who is cast in soloist or corps roles, the students decided for themselves. Every student received the same exam. There were two sets of problems: Corps and Soloist (Figure 3). The Corps problems were familiar ones taken from Engineering Links, stretches, in-class activities, and quizzes. These problems made up 70-75% of the exam. All of the students needed to complete the Corps portion. If the Corps problems were solved or answered correctly, the student earned a C. Poorer performance on these problems earned a D or F. Doing well on the Corps portion meant that the student had acceptable proficiency with the material. This portion of the exam follows some of the tenets of mastery-based grading, which deals with various strategies to have students master certain aspects of a course as represented by an exam [13]. The Soloist questions were much more challenging requiring more thinking and in-depth analysis. Solving or answering the few soloist questions earned the student an A or B depending on performance. Doing well on the soloist portion of the exam corresponded to a high level of proficiency with the course material. It was up to the students whether they attempted the soloist problems on the exam.

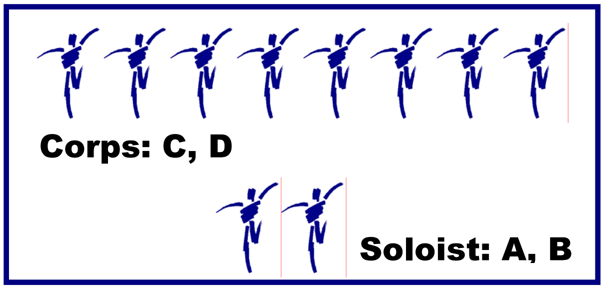

FIGURE 3
SOLOIST AND CORPS PERFORMANCE LEVELS.

There were certain caveats to the casting for Corps and Soloist levels. In order to be eligible to attempt the Soloist problems students needed to show a minimum level of proficiency with the material ahead of time represented by their performance on weekly quizzes and regular attendance in class. These added the key aspect of accountability to the student's performance prior to the exam.

Casting for exams was done partly to reduce the student's stress level in preparing for and taking exams. Every student should not be expected or required to perform at the same high level. Students need to learn enough of the material to have a certain level of mastery of the subjects and applications. This level does not need to be extremely high for all students. Not everyone can be, or should be, in the Soloist role.

II. The Role of Repetition

In the practice required of every performing art there is a lot of repetition. Musicians play scales, dancers do pliés, the repetition of basic elements is at the core of learning the material. The learning that occurs is profound and lasting precisely because the actions are repeated so much. Engineering education needs to have more repetition built into the curriculum, the class sessions themselves, and the practice (Engineering Links) that students do. It is not enough for students to solve a problem once; they need to do this same problem many times. The same idea applies to the activities done in class – these need to be truly practiced so that the material, topics, concepts, and applications get into the student's mind *and* body. It is much like "muscle memory" in dance. To help foster increased repetition of problem solving by students, the importance of repetition in performing arts and in sports was discussed numerous times during class. We had students keep an Engineering Links Notebook, similar to a laboratory notebook, to capture their problem solution attempts. We made this notebook one of the themes of the class; the more in it, the better it was. It is too early to tell whether this strategy improved student learning and performance although it appeared to help students solve more Engineering Links on a regular basis.

SUMMARY

Engineering educators can capitalize on the successes common in classical ballet class to create better engineering classes. We can instill and inspire a striving for excellence in engineering class the way it is in ballet class. We can engage students and hold them accountable for their learning in class. We can bring the sacred space ethic into the classroom to pave the way for success in the engineering profession later on. We can create an atmosphere where students look forward to and demonstrate excellence in performance whether on an exam in college or each day on the job. Engineering can gain a great deal from classical ballet and the performing arts.

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