Drama: An Emerging Model to Teach Engineering Design and Team Dynamics

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Introduction

Is it possible to design a better team-building model that integrates engineering design and team dynamics? And if so, can such a model improve an instructor's effectiveness? As educators at the Colorado School of Mines (CSM) who teach design and teamwork to first-year and second-year students, such questions are a primary concern to us. Four factors converged on campus at CSM during the spring semester of 1997 that provided a potential answer: (1) The Student Council for Mines Little Theater (MLT) voted to allow an all-student production team to produce the musical, *The Music Man*; (2) two of the three professors involved with the project have extensive backgrounds in theater; (3) one of those two professors happened to be teaching a sophomore level Design (EPICS) course that semester; and (4) the third professor, a design engineer by trade and passionate inclination, auditioned and acted in the production. This article reports the insights we gathered observing this all-student production team in action and, based on these findings, to propose a working model to develop and to teach teams in design, leadership, management and communication.

Engineering design, a complex, interactive, and creative decision-making process, evolves as the design team synthesizes information, skills, and values to resolve open-ended problems. To help students become skilled at this process, mentors in the Design (EPICS) program at CSM have students learn through practice. The centerpiece of each design sequence is an open-ended problem that students work in teams to solve. Although the mentor's primary role is to apprentice students through their difficulties, they also furnish students instruction or information in carefully selected topics. "Hands-on" application of engineering practice skills facilitates students' learning, specifically of computer-aided design software applications.

Central to the curriculum is a project which requires teams to make decisions based on assumptions and constraints imposed by the problem, situation and client. This project provides an opportunity to exercise both creative thinking (brain storming and data gathering) and critical thinking (technical assessment and economic analysis). Teams assess various design parameters to develop the "best" solution through evaluation, analysis and synthesis of alternatives.

Second -Year Students Propose A Project

Second-year students proposed to the Director of Design (EPICS) that they use their production of *The Music Man* as a design project in lieu of more traditional engineering projects. The

instructors met with the students late in the fall semester of 1996 and expressed concerns that their proposal may not meet some course requirements. Our primary bone of contention involved the technical aspect of the project proposal and the lack of a client representative. The students argued that the same design process principles taught in Design (EPICS), illustrated in Figure 1, can be used to engineer a musical production. Namely, they had to identify goals, develop specifications, gather data, define options, prepare a plan of action and implement the design, which, in this case, was their production of *The Music Man*. These students resolved the client issue by approaching the faculty representative on MLT Student Council to volunteer. He supervised production expenses and signed off on the budget; so the team simply appropriated his duties as the producer to function as those of the client.

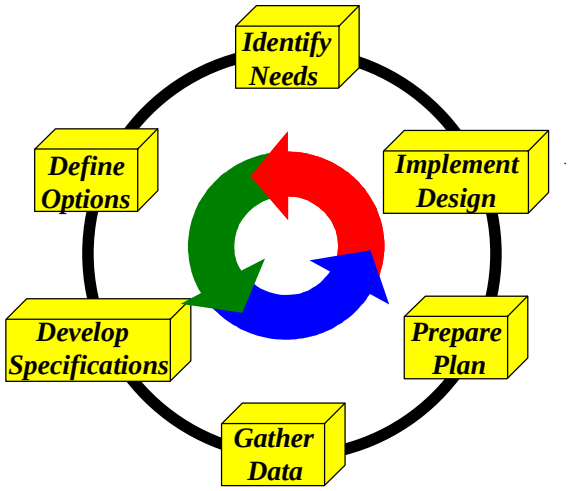

Figure 1: *Engineering Design Process Applied in the Design (EPICS) Curriculum*

Was it pure coincidence that this all-student dramatic production of *The Music Man* was also the 25 year alumni anniversary of Mines Little Theater? That the goals were high? The risks great? The task of organization daunting? Which all somehow contributed in the end to make this project a success? Or was there at work here an underlying structure that better integrated team processes? We began to wonder.

A Proposed Engineering Design Skills Matrix

Skills and procedures important to the engineering design process (i.e., engineering design method, leadership, management and communication) evolve from project inception to completion in four phases (inception, research, systems analysis, and implementation). In the matrix, summarized in Table 1, we correlate elements of each of these skills in accordance with these

Table 1 ***Proposed Engineering Design Skills Matrix***

Inception	Research	Systems Analysis	Implementation
Design identify needs, define specs.	Design gather data, redefine specs.	Design define options, evaluate options, prepare plan.	Design implement plan, evaluate performance .
Leadership set positive environment, develop relationships, build team spirit.	Leadership negotiate conflict, delegate responsibility, encourage participation.	Leadership facilitate member ideas, negotiate disagreements, nurture common ground.	Leadership maintain progress, manage panic and frustration.
Management set ground rules, define scope of work.	Management set roles and tasks, prepare work plans.	Management develop schedule and resource allocation.	Management troubleshoot, resolve schedule and resource issues, document .

Communication	Communication	Communication	Communication
encourage member anticipation and optimism, develop relationships.	resolve conflict, build trust, encourage openness.	encourage members to accept membership and roles.	recognize individual contribution and performance.

four phases. Skills combine with and reinforce other skills during each phase to produce a more cohesive team dynamic.

As an example, during the systems analysis phase, the design team evaluates alternatives (a component of the design methodology) which requires that they develop a schedule and allocate resources (management issues). Team leadership must facilitate the integration of member ideas and must negotiate disagreements as the analysis proceeds. Supportive communication within the team encourages member involvement in the team's processes (i.e., strategic thinking, decision-making, etc.). Some might argue that to "facilitate" and "encourage" are, in essence, the same task. However, "encourage" and "facilitate" have related but different meanings. *Facilitate* means "to free from obstacles; make easier; aid, assist;" whereas e*ncourage* means "to continue on a chosen course, to impart courage and confidence" [1]. Though closely aligned, these two tasks actually carry out different functions within the team's dynamic. The former is more a leadership issue while the latter a communication issue. The model demonstrates how closely aligned these two different team functions actually are and being able to do so is what gives it its power.

Development of skills within each phase strongly suggests a more fundamental process working here than simply coincidence. Correlation of similar types of team processes evolving in distinct phases strongly indicates a deeper, underlying structure. If this hypothesis is true, then knowledge of such a structure would certainly improve an instructor's effectiveness in teaching and a student's learning of engineering design and team dynamics.

The Postmortem: What the Students Learned

MLT's musical production, *The Music Man*, closed on April 19, 1997 to a sold out audience. The students gave their final presentation, the postmortem, to the rest of their Design (EPICS) class on April 30th. The ensuing discussion proved to be informative and insightful, not only for the students themselves but for the entire class and faculty as well. The postmortem addressed one basic question: What skills did the students learn about project development from the drama experience? To answer this question the students divided their presentation into four skills areas based on the problems and issues they had to overcome.

Design: The students admitted they drastically underestimated the many hidden design variables in producing their musical; namely, in terms of research, time commitment, resources and strategy. They repeatedly re-analyzed their approaches and improvised to keep on track and accomplish all their stated goals before opening night. Their team motto became "Always expect the unexpected." As an example, they would have preferred to rehearse on the stage as the set was being built; that way they could have worked out beforehand many of the physical design problems (i.e., the choreography, staging, scene changes and band accompaniment, etc.) to help facilitate their design [2, 3] However, because MLT theater doubles as a large lecture hall, the students had restricted use of the stage. Instead they were forced to work in groups and integrate

the components shortly before the dress rehearsal. This method limited the amount of authentic practice required to work through the timing issues. Engineering teams run into similar problems when clients change major design specifications well into the implementation phase.

Leadership: According to the students, the team's leadership centered on learning how to deal with their hidden personal and political agendas that undermined their collective effort. Who was to take control and how much? This problem arose because the director, inexperienced and somewhat intimidated, cautiously embraced the role of leadership; consequently, her assistant, who was herself quite experienced, usurped her power in the name of saving the production. Though heroic, the assistant's actions threw the rest of the production team into confusion [4, 5, 6]. The team soon realized that to gain control of their project, they first had to establish specific roles with specific responsibilities. Furthermore, they had to learn how to separate their friendships from their professional relationships and commitment to the team. Within the industry, engineering design teams also struggle with the political environment of an engineering problem and need to constantly redefined team roles.

Management: When students discussed the management of their project, they not only talked about scheduling and organization problems, but also a need to establish clear, achievable goals and ground rules [4]. They quickly realized that with each passing day, opening night was encroaching, and not much was getting accomplished. They formulated a master schedule that listed all the tasks for which each was responsible, and the deadlines when each task was due. By this method they were able to better divide and delegate the labor, budget their time, organize their meetings and rehearsals, network and align their resources to make ready their production [7]. More importantly, they understood why effective, coordinated planning was crucial for team success.

They also realized they had to establish ground rules -- agreed upon by all the members on how they would conduct themselves in order to build momentum and gain headway. The importance of maintaining clear team goals, we believe, is best summed up by one student's comments: "Everyone working towards the main goal will keep you going when it doesn't appear you can go on any longer and want to quit. Keeping an eye on the main goal allowed me the patience to deal with some pretty difficult people. I could better accept the flaws of myself and others to accomplish what we had to do" [8]. In the end, the students learned to be flexible and adapt to the other members' individual working styles -- not an easy feat! In industry, management plays an important role in the overall success rate of the engineering design team.

Communication: Good communication is the "glue" (the students' term) that holds the team dynamic together. In the beginning, the students tried to spare each others' feelings by not being direct and honest in discussing the problems of the project. They soon realized, however, that by withholding the truth and not communicating openly, they began to not trust each other. Their team morale plummeted. To save the situation, they learned to improve their listening, feedback and discussion skills; whereby they established clearer information channels, kept more complete written meeting minutes, and made explicit what each expected of the other [7, 9]. With this new understanding, the students began to work together like a team. Clear and effective

communication often determines whether an engineering team succeeds or fails to deliver their product to the client on time and within budget.

Our Observations

We observed one overriding theme: Even though the students divided their experience into four categories, they were hard pressed to discuss the experiences they encountered as isolated incidents. For them, design, leadership, management, and communication were integrated team processes. The context of producing the musical forced these students to think of these processes as subsystems of a larger system that affected and had repercussions not only within but also outside the team; namely, the cast, band members, tech crews, faculty, school and immediate community at large. It is evident that the students' thinking changed from primarily a dualist, linear mode to one that was more multidimensional and lateral. That is, they stopped thinking in terms that were exclusively binary and rigid (black/ white, right/ wrong, yes/ no) and started thinking in terms that were more conditional and strategic (what if, how about, perhaps/ maybe) [10, 11]

Furthermore, we observed that the students' mode of "systems" thinking was considered by some faculty as being "soft" and having nothing to do with what real engineering design teams encounter. It is interesting to note there seems to be a difference of opinion between what some faculty perceive to be the skills their graduates need to survive in the market place, and the skills industry and business claim their graduates actually do need [12]. However, even faculty who found that the drama project produced convincing results in terms of teaching team management and communication, seriously wondered whether producing a musical is an authentic engineering design project. This concern is valid, deserves honest consideration and should be addressed directly.

We concede that an engineering design model based on drama may not teach the specific design principles of, say, metallurgy, chemical or petroleum engineering. Our objective, however, is to propose a model general enough in application to integrate principles of design engineering, leadership, management and communication, and yet at the same time also function as a framework to interface with specific engineering design disciplines. Since these skills are in great demand by industry and business today, the issue seems to merit our attention and further investigation. Therefore, we propose that an interfacing process exists that integrates subsystems of design, leadership, management and communication; that an underlying structure does emerge in preparing a theater production that incorporates these processes and can be adapted to teach teams the principles. By proposing drama as a possible model to teach engineering design, leadership, management and communication (learning objectives that are consistent with the Design (EPICS) Program), we do not advocate that engineering/science students and faculty across the CSM (or any) campus start to produce musicals to learn these skills. Such a proposed model, however, would greatly improve cross-functional team member interaction and better integrate the many disciplinary viewpoints on a given project team to deliver one product [6, 13, 14].

Improved Multidisciplinary Team Member Interaction

The engineering design process drives our proposed model. The process is presented in a general format for one purpose: To create a common knowledge base to function as a framework and interface with the other specific engineering disciplines. The framework offers the team manager processes and procedures for each phase but not the technical knowledge, skills and know-how. Team members bring these ingredients to meet the project's design objectives and system analysis.

Developing a high-performance team is one of the most difficult challenges facing professional project managers everywhere. Most high-tech teams are multidisciplinary and depend on a well-balanced interdependent membership. Team managers must smoothly integrate these different engineering perspectives to deliver one product; and, equally important, they must also cope with a multitude of interpersonal issues that are always present in any teamwork environment. Though trained to be rational and objective, engineers are still human. If these issues are not handled intelligently and constructively, they can quickly derail the best-intentioned projects. Working out hidden interpersonal issues is the biggest obstacle in creating a well-balanced interdependency. Interpersonal conflict within a team usually manifests as either leadership, management and/ or communication issues [6]. A primary skill for any successful project manager is knowing not only what inter-team issues to address and how but when.

Since design drives the team's effort, we keyed the leadership, management and communication issues to each phase where they most likely occur in the process [15, 16, 17]. In this way, the model also offers a framework to guide the engineering team through the common interpersonal issues that arise as the members work out their relationships and responsibilities as the team and design project evolve. If the proposed model can help build interdependency among the various member viewpoints, in addition to predicting to some degree the hidden interpersonal issues in the team's path, then such a model would likely improve multidisciplinary team interaction.

Conclusion

The need to improve methods in teaching essential team skills to keep pace with the demands of the current market place is well documented. Through observing an all-student production team prepare MLT's spring semester production, *The Music Man*, we noticed the students' developed a "systems" thinking mentality that progressed in four distinct phases, which correlate well with the maturation cycle of each of the team skills discussed in this article. This observation lead to the following inferences: Team skills combine with and reinforce other skills in separate phases to produce a more cohesive team dynamic. More importantly, the correlation and development of team processes appears strongly to indicate a deeper, underlying structure that merits further investigation. We outlined a model that suggests a structure general enough in application to integrate team principles of engineering design, leadership, management and communication, and yet can also function as a framework to interface with specific engineering disciplines like metallurgy, chemical and petroleum engineering. We propose such a model would greatly improve teaching cross-functional team member interaction and better align the many disciplinary viewpoints on a given project team to deliver one product.

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Biography

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Abstract (IEEE)

Is it possible to engineer a new team-building model that better integrates design and team dynamics? In lieu of a more traditional design project, a group of Colorado School of Mines sophomore students mounted and produced Mines Little Theater's spring musical, *The Music Man.* The production closed on April 19, 1997 to a sold out audience. The students presented their final presentation on April 30th. Their presentation was to answer one question: What skills did the students learn about project development? This paper reports the insights gathered observing this all-student production team in action and based on these findings, proposes a new working model to teach basic principles in engineering design, leadership, management and communication. In their presentation, the students divided their experience into four categories; however, for them, design, leadership, management and communication were inseparable team processes. Producing the musical forced these students to think of these team processes as an integrated system. The students' systems thinking evolved in four distinct phases; which also coincided with the development of each team skill set (engineering design, leadership, management and communication). From these observations, this paper outlines a proposed team-building model that demonstrates: (1) How each team skill set develops in four distinct phases; (2) how each skill set combines with and reinforces the other skill sets in each separate phase to produce a more cohesive team dynamic as a whole; and (3) how the correlation and aggregate development of each skill set within each phase strongly suggests a deeper, underlying structure. The proposed model presents a framework general enough to integrate principles of design in engineering, group leadership, team management and communication, and yet can also function as an interface with design specific engineering disciplines.