Principles of living systems and engineering design for freshmen level students in biological engineering: design of a tiger habitat

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Abstract

The design of a tiger habitat for LSU mascot Mike the Tiger was assigned as a class project for BE 1252: Biology in Engineering, a required freshmen level course in the Biological Engineering Curriculum. This project was chosen because of its relevance in illustrating the boundary between living systems (animal, human and plant) and the environment, because of its proximity to and interest for students, and because of the ease with which students could grasp the intricate nature of a biological engineering design problem without high level math skills. Emphasis was placed on "big picture" concepts involved in design, including the engineering design method, methods of evaluating decisions, and consideration of differing perspectives and how they affect the final design. Students worked in teams to create initial designs, then consolidated and prepared a final design, which was presented to a panel of tiger habitat design experts, and a university administrator. Student motivation for this project was very high, and all students reported that the tiger project was illustrative and helpful for them in understanding concepts involved in biological engineering design in an end of the semester evaluation. Students continued work on this project after the semester ended, and are attempting to propose their design to the university community for implementation. In this paper, the rationale and methods for using this project in a freshmen level design course are presented, and the results and implications are discussed.

Introduction. The tiger habitat and proposal to the university resulted from a design project assigned in Biological Engineering (BE) 1252: Biology in Engineering. The second of eight core courses in LSU's Biological Engineering curriculum, the description of this freshmen level course was as follows: effect of variability and constraints of biological systems on engineering problem solving and design; engineering units; engineering report writing; oral report presentation; laboratory demonstration of biological engineering analysis. Thirty students were enrolled in this course.

One major facet of the course was the class design project. This semester long, guided exercise introduced students to the engineering method and attributes of design. Emphasis was placed on "big picture" concepts involved in design, including the engineering design method, methods of evaluating decisions, and consideration of different perspectives and how they affect a design.

The tiger project was chosen for several reasons. Because BE 1252 is a freshmen level course, the instructor cannot assume that students have had calculus or physics. Thus, there is little emphasis on engineering calculations. However, students can gain an appreciation of the engineering method and on how to approach problems from a "big picture" standpoint without high level math skills. If the instructor points out where in the process (and a little of how) engineering calculations are necessary, but shows this in the larger context of approach, synthesis, evaluation, communication and implementation of designs, the students will gain knowledge of the design process, and an understanding of the fundamental courses necessary for an engineering degree.

The tiger habitat design is an excellent example of a biological system. Students had to learn about "the biology of tigers" in order to synthesize an effective design. Students also had to consider the interrelations among biological systems, including the environment surrounding the tiger, and the interface between tigers and humans. This approach made explicit an important paradigm shift central to biological engineering: to let the biology lead the design. In this case, this means building the enclosure around the tiger's needs, instead of building the enclosure and putting the tiger inside it. For example, before thinking about building materials, the students had to consider the outside environment, and the needs of the tiger. Having researched these areas, the building materials needed were then chosen.

Finally, the tiger project was chosen as a motivational tool. Because Mike the Tiger is the LSU mascot and is strongly tied to school sports and spirit, the students were excited about creating a better living space for him. Because motivation is often a problem for engineering students during the first two years of study[1], the link between doing quality work on the project and having it accepted by the University administration was stressed. The majority of students surveyed in this class reported that they were in biological engineering to serve people and better society. This project was assigned to appeal to this need as well.

Methods. The design project was used/studied throughout the semester. Exercises were given to correspond with steps encountered in engineering design. The following table describes the assignments and lab exercises conducted during the course.

activity	time during the semester	significance to the design process
introduction of the situation	1	identification of the problem

Internet and library searches	1	information gathering
seminars from experts	1,2,3	information gathering
brainstorming	1,2,3	search for creative solutions
decision charts	2,3	evaluation of preliminary designs
discussions with experts/instructor	2,3,4	evaluation/selection of preferred solutions
AutoCAD drawings, proposal writing, oral presentation	4	communication of design
critique by expert panel	4	evaluation of design

Note: Numbers 1 - 4 listed in the *time during the semester* column indicate the quadrant of the semester that the activity was performed by the students, with 1 representing the first quarter of the semester (weeks 1 - 4) and 4 representing the last quarter of the semester (weeks 13 - 16)

Information on tigers and tiger habitat design was presented in class through movies, lecture, discussion, field trips to habitats, and seminars by experts. Students also gathered information on tigers and habitat design on the Internet and in the library.

Initial study and observation of the current cage were performed by students individually. They were then split into six groups of five students each. Within groups, students were responsible for dividing the work load amongst themselves, and for governing themselves. Students voted to merge their groups from six to two with approximately four weeks left in the semester. This resulted in the formation of a twenty member group (for a new habitat design), and a ten member group (improving the existing design).

Each group presented its design and proposal to the class with two weeks left in the semester. Subsequently, the final design was decided upon by the students through group discussion. The final proposal to LSU administration for implementing the design was obtained by merging the proposals presented by each group. The final design and proposal was presented for critical review to a panel comprised of two tiger habitat design experts from the Audubon Institute in New Orleans, and a University Administrator. This occurred in the last week of the semester. Students were required to complete a self-assessment narrative discussing their experiences with the tiger project as part of the final exam for the course.

Results and Discussion.

Instructor and Student Reflections. The tiger habitat design project accomplished a number of goals considered important by the instructor. The most important feature of this project was that students were able to participate actively in a design project. Because they were starting from "ground zero," they were able to: (1) observe the importance of research to the design process; (2) create designs and present two and three dimensional drawings of their renderings using AutoCAD, a skill they learned in the first BE core course; (3) recognize the struggle and synergy involved in working with groups; (4) realize the importance of oral and written communication in the design process. The instructor considered all these aspects important for freshmen to experience.

Students were highly motivated with respect to this project because they realized that it could be actualized, and that the harder they worked, the better chance their ideas and designs

would be accepted. Also, by emphasizing the importance of designing for the tiger's needs, the students were able to create designs using a biological model, rather than using physical models to fit a biological system. The instructor felt that this concept of letting the biology *lead* the design is important to the cultivation of biological engineers.

Based on the students' final design and proposal, the instructor believed that almost all students mastered the engineering method, and gained insight into the recursive nature of this process. All students reported that the tiger project was illustrative and helpful for them in understanding concepts involved in biological engineering design in an end of the semester evaluation. The following student comments reflect instructor thoughts:

* I liked this part of the course, in that it allowed us a bit of free reign to be creative, implement our own ideas, and find out about the design process

* Creating the design forced us to think about as many problems that we would encounter as we could. Knowing where most of our problems would be caused us to brainstorm about how to solve those problems. Our brainstorming led us to the Internet and other sources such as facility services and animal experts to get more ideas and to polish up or throw away the ones we had. This project showed us how engineering works and it actually stimulated our minds. This is a great way to learn when compared to reading the same sort of thing from a book or mindlessly working problems over and over again.

* Overall, I enjoyed and thought that the tiger project was a good idea for this class. I think this was a very difficult project though, especially for inexperienced engineers. The reason that I thought this project was difficult is the fact that the information that we needed, based on our knowledge and experience, to complete this design, was not clear-cut or easily accessible. We had no guidelines to follow from a book; maybe this reinforced the steps in the engineering design method. I realize that this may be or is a common problem for engineers and especially biological engineers. Nonetheless, I think that we could not have asked for a more interesting and unrestricting project to learn the basics about design and engineering.

Although the experiences of students and instructor were primarily positive, some obstacles were encountered. One challenge the instructor found intriguing was the students' response to experts with differing perspectives. Many students had a difficult time using critical evaluative skills; in general, they were highly swayed by what each expert was saying without taking into account the perspectives regarding each speaker.

For example, four tiger habitat experts affiliated with zoos instructed students on the importance of using a natural substrate for the tiger's physical well being. A concrete surface was strongly discouraged due to its abrasiveness (causes bleeding and soreness on a tiger's pads), and hardness (causes arthritis in the legs and back of a tiger). The students interacted with these experts on numerous occasions and chose to use dirt and grass in their design. However, when two veterinary students responsible for Mike's day-to-day care said that concrete was easy to clean and that dirt might cause fungal infections, the students then thought that concrete was the best surface to use. The veterinary students were the last speakers that the students interacted with, and it was their recommendation that the majority of students thought was "right."

This result is consistent with Pavelich and Moore's finding[2] that freshmen usually exhibit dualistic thinking as characterized by the Perry Model[3]. Dualism is characterized by absolute thinking, that one thing is right or wrong, and that an expert knows everything. The perspective of the experts is not taken into consideration. One student comment showed that he had transcended dualism:

* I learned that when talking to people for advice regarding design of something, you will often get contradictory opinions. Different people will look at the same design from different angles depending on their experience with the object being designed. I learned that often there is no standard to go by in designing something. You often have to make it up as you go along, using the best information available at the time.

Another challenge occurred in the governance of the groups, particularly after students had merged from six to two groups. Many students were frustrated with their experiences; some felt that they were carrying the majority of the work, and the students' varied schedules and opinions made it difficult for them to meet together outside of class time, and to agree on how to complete the final design. This frustration manifested itself in the form of blame, as the students blamed other members of their group and the instructor for not having a better experience, or better final design. Although the instructor could have provided more structure for helping the groups achieve efficient self-governance, it is believed that the struggles in this experience are an important part of developing interpersonal communication skills.

Students were asked to assign themselves a letter grade based on their performance for the project. The mean GPA of the students in the twenty member group was 3.3/4.0, and the mean GPA of the students in the ten member group was 3.0/4.0. This occurred even though the ten member group's project was of significantly more detailed and of higher quality than the twenty member group's project. The instructor believes that this result is due to the students' method of self-assessment. Most students graded themselves based on completing the work assigned to them. If the student completed the work, s/he usually assigned an A. Because the larger group had the same amount of work as the smaller group, members had less responsibility, and completed their tasks in much less time. One student assigned himself an A for looking up the cost of nails and lumber; because this was the only task assigned to him, and he completed it, he assigned himself an A. Members of the larger group seemed to have less commitment to the project than members of the smaller group. It appeared that the smaller group dealt with issues of quality that the large group did not discuss. The instructor believes that this was due to management problems and the size of the group. A sampling of student comments on group work is as follows:

* I feel that my group's problems stemmed from an inability to compromise, a lack of structure amongst the group, and a lessened feeling of responsibility toward the project in the team members due to the size of the group.

* Unfortunately, neither group really had any sort of governing system to keep them productive; both groups basically dissolved into anarchy. Anarchy in a ten person group is just easier to control.

* The problem that occurred with the combining of the groups was that the group was thinking as a group and not as a bunch of people with good ideas. If a group is to succeed it needs the sum total of all the brains in the group and not just a few.

The design. The 6500 square foot design is 3.5 times larger than the current cage, sports Italian Renaissance architecture consistent with the style of LSU, features glass viewing areas instead of bars, and contains a natural habitat with numerous types of flora, a varied terrain, and a pool, stream and waterfall system. Off exhibit areas include a medical facility, a keeper office, and two den areas to facilitate the addition of a second tiger to the exhibit. A complete enrichment plan is also part of the design; this comprehensive list of activities will provide mental and physical stimuli for Mike in his new surroundings. The top of the enclosure is covered with wire mesh.

Recommendations. 1. *The instructor should provide the students with more structure for interacting in groups*. While group governance was left up to the students, insufficient guidelines were provided to the students with respect to possible models for interaction. The instructor reviewed literature for working with groups[4-6] and has had much better success in subsequent classes using the following strategies: (1) assigning groups with respect to gender and minority issues; (2) assigning academic **and** group oriented objectives; (3) presenting group interaction models in class; (4) meeting with a representative elected by each group during the semester to discuss progress and concerns within the groups.

2. *Make the connections between what is studied in class and the connection to the engineering method more explicit*. Many students were anxious about the open ended nature of this design problem. By providing structure through emphasis on the role of each assignment with respect to the design project, the instructor has had less anxiety with current projects. For example, students used brainstorming exercises to generate preliminary designs. In subsequent classes, the theory of creativity was presented and discussed, a creative lab exercise was introduced in class, and the role of creativity in the design process was studied. Armed with this information, the students had a better springboard for brainstorming exercises with respect to their design projects.

Conclusions and current status. Thirty students worked individually, in groups of five, and in large groups to create and refine a wildlife habitat design and enrichment plan for LSU mascot Mike the Tiger. This design, and a proposal to the LSU administration for its implementation, was the final product of the project. The instructor and students believed that the project was an effective means for introducing the engineering method to a biological system. Problems were encountered while working in large groups, and suggestions for remedying this problem are discussed.

Six of the thirty students continue to improve the habitat, which has given them a sense of the iterative nature of design. Students and instructor met with tiger habitat design experts at the Audubon Institute over the summer, who have generously continued to critique designs and suggest improvements. The group has been invited to present their project to the University Planning Committee when the design is complete. Currently, students are working with engineers and architects to prepare detailed design specifications. They have also created a web site at http://gumbo.bae.lsu.edu/TIGER, where the proposal to university administration can be viewed.

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