Experiences in Teaching Sophomore Design in Mechanical Engineering

Author:

Richard Bannerot, Mech. Eng'g, University of Houston, Houston TX 77204-4006; rbb@uh.edu

Abstract — *This paper will describe two types of design and build team projects appropriate for an introductory engineering design course. The two types of the projects are: semester-long, (major) team projects and two-to-four week (minor) individual or small team projects. The guidelines for developing successful semester-long projects will be presented first. The guidelines will be followed by a list of the "DO's" and "DO NOT's" for project conception, development, expectations, management and evaluation. Specific issues that will be addressed are: team formation, team size, team mentoring, varying skill levels between teams, spreading the "pain", discouraging last minute construction, grading methodolgy, reporting requirements, design for assembly, monitoring, and project selection/development. Issues related to project selection/development are safety, compete against the clock not each other, limited operator participations, expectations, design testing and evaluation, and esthetics. Two examples of minor team projects that involved students from both inside and outside the class will be described. These projects involved:*

- *teams of engineering and art students worked on small projects together and*
- *teams from similar design classes in two different cultural settings (University of Houston and Kanazawa Institute of Technology in Japan) working independently on the same small design project.*

Both of these examples present interesting design situations. While design is central to both art and engineering, it is taught differently in each discipline. So in the first example, the two groups of students bring different backgrounds and perspectives to the design process, but they must now work together. Also, the art students are usually well acquainted with subjective, open-ended problem solving while this activity is still new to most engineering students. In the second situation, American and Japanese students are working independently and are shown to develop significantly different types of solutions to their common problem due to the cultural differences between the two groups. These different solutions help to make the point that non-technical issues can not only provide the basis for design constraints and goals, but they can even dominate the technical considerations for a design to be successful.

Index Terms — *design projects, introductory design, interdisciplinary design, working in teams*

INTRODUCTION

Since 1991 the author has taught, each fall and spring semester, a required, project oriented, introduction to design course at the sophomore level in the Department of Mechanical Engineering at the University of Houston to between 35 and 55 students. While the course content has changed very little over the past ten years (engineering in the global prospective, the design process, shop practice, introduction to manufacturing, engineering communications, specifications, personality and group issues, codes and standards, intellectual property, engineering ethics, and introduction to engineering economy), the projects have changed every semester.

The course is usually the first engineering course taken by a mechanical engineering student. Therefore, part of the course objective is to introduce students to, and build their confidence in, problem-solving. During a typical semester, one major team project and two or three minor projects (individual or team) are assigned. While the intent, extent and format of the minor projects change each semester, the format, structure and the evaluation process for the major projects (which change each semester) have evolved to a more or less steady state and remains the single most significant part of the course counting for as much as 50% of the course grade.

MAJOR TEAM PROJECT

The major project is presented to the class in the second week of the course and continues throughout the semester. Among the delieverables are: a working device which satisfies a set of constraints and performs satisfactorily, written progress reports, team meetings with the instructor, initial testing (proof of concept), final testing in which success in approaching specified goals is measured, a final written report, a final oral presentation and a device for evaluation. Team performance on all of these "requirements" contribute to the final grade for the project and remove much of the "pressure" for a device to "perform" at the final testing, i.e., the execution of the design process is viewed as an important part of the evaluation of the project.

The three credit-hour course is organized as a two-hour lecture (for the entire class) one day each week and a three-hour "work session" limited to about 24 students each week. On average about 45 students enroll each semester, so there are usually two "work sessions". The "work sessions" are used for various purposes including formal student presentations, prototype testing, shop tours, scheduled instructor meetings with individual teams, and "work on project time." On the first day of class, the students are told that in their "work session" that week they will be expected to make a three to five minute oral presentation. The topic is open, but they are told that it is preferred that they talk about themselves and most do. This experience serves two primary purposes: first, few of the students know anyone else in the class so these presentations allow the students to introduce themselves (very helpful since design teams will soon be formed) and second, several oral presentations are required during the semester and the more these are practiced the better.

The first lecture is used to put "design" in perspective with "engineering" and to introduce the design process. Machine tools, shop practice and manufacturing processes are reviewed in the lecture in the second week. The major project also begins with the distribution of the project description (usually a ten to twelve page document). A brief overview of the project is also given. Each "work session" is divided into four groups (about 6 student per group) and scheduled for a machine shop "experience". For the next two weeks each group will attend a ninety minute session in the Department Machine Shop in which they will participate (with one of the Department machinist) in the production of a simple metal part utilizing an engine lathe, a vertical mill, a vertical and a horizontal band saw, a drill press, grinders, and a tapping set. The operations of various other hand tools (e.g., calipers, micrometers, broaching set, etc.) and many of the accessories for the machine tools (e.g., various three and four jaw chucks, various bits, borers, taps, etc.) are also demonstrated. A handout is provided which describes the operations of all the standard shop tools. Shop drawings are discussed from the machinist's perspective. There is also a demonstration of an NC machine.

This shop "experience" takes two weeks to accommodate all the groups. On their "off week" the students are encouraged to begin their preliminary ideation for the major project. The lecture in the third week continues a discussion of the design process and includes a (usually lively) discussion of the major project. Students are expected to be formed into their project teams by the lecture of the fourth week and each team provides the instructor a list of its four team members, contact information and a preliminary team name. It is expected that the name of the team will be consistent with the "spirit" of the design and will be reflected in the esthetics of the physical device produced and in their reports, e.g., logos (both written and oral). Teams are allowed to change names as their designs and understanding evolves.

The "work session" in the fourth week is free time for the teams to begin work on their projects. Each team is also introduced to its mentor (an undergraduate who has completed the course) and to the small shop available for the construction of prototypes. The shop provides a variety of hand tools, a place to work, but only a few power tools. The mentors supervise the small shop and schedule the work sessions for the teams as needed. Usually each mentor will take two teams. The mentor's main responsibility is to help and motivate (as needed) the teams and to report any apparent team dysfunction to the instructor. If the team prepares its reports in a timely manner, the mentor is available with feedback before "official" submission. The mentor does not take an active role in "leading" the team, but will offer suggestions, especially if unrealistic designs are beginning to emerge. For the most part the teams are not sufficiently organized to take full advantage of the opportunities provided by the mentors. The mentors are provided a "group" office with a phone, refrigerator, and study space and a separate room with computers, printers, etc. (This space is their perk.). The mentors are also available to assist the instructor during the testing and competition. The mentors do no grading.

During the fifth week "work session" each team must meet with the instructor for a half an hour and present an informal oral report on their progress and problems. Usually, any team dysfunction issues are addressed at these sessions, both those self reported by the team and those identified by the mentors.

Formal, written progress reports are due in the sixth week and tenth weeks. Additional information on reporting requirements can be found later in this paper.

The major activity for the seventh week is usually the Initial Test (or Test of Concept). A device capable of achieving a reduced set of objectives under a reduced set of constraints must be presented for testing in the "work session." The evaluation is "pass" or "fail". Teams successful in their first attempts are awarded "10" points (out of the 100 points for the project); fewer points are awarded for success in subsequent attempts. All successful teams are qualified to compete in the Final Test (the Competition) in four weeks. Unsuccessful teams (during the Initial Test) must demonstrate a successful design within the next week (receiving significantly reduced credit) or they are not allowed to participate in the Final Test. During the next three "work sessions" each team will meet with the instructor at least once, twice if the team is having trouble. Otherwise the "work session" time is available for project work.

The Final Test is usually scheduled in the eleventh week. The event is presented in the atrium of the Engineering Building and usually draws a crowd. The student newspaper and, on a newsless day, one of the local TV stations may show up. For the Final Test each device must be under a specified mass, must be deployed from a box of limited size and operate within a limited space. The device will usually move things (e.g., golf balls, softballs, ping pong balls, constructed objects, etc.) according to a specified pattern, within a specified time interval. No "outside" energy sources are allowed, i.e., taking energy from beyond the allowed space. Electrical and chemical energy is allowed, but gravity is the preferred source of energy. All weights, batteries, etc., are counted as part of the weight of the device. The device must satisfy several operational constraints and attempt to maximize a Figure of Merit based a series of performance goals. Multiple attempts are allowed, but devices endure penalties if not successful during the first set of attempts. The Final Test is worth 25 points (out of 100 for the project). Points are awarded according to the device's Figure of Merit and other potential bonus points, which are all performance measures, e.g., the least mass, the smallest device, and closest to the time goal.

The "work session" is free the next week as the teams prepare for their oral presentations. Each team in its normal "work session" for the thirteenth week will be given 20 minutes to present their "case" and to sell their device and its design in a formal. PowerPoint oral presentation. As part of the presentation each team must demonstrate that its device satisfies all constraints and performs satisfactorily. The presentation is worth up to 10 points and teams are encouraged to be innovative. Many dress in matching outfits. Each successfully performing device is impounded after the presentations and evaluated by the instructor. The major criteria for evaluation are: 1) concept (uniqueness and appropriateness of the design concept); 2) creativity (execution of the concept); 3) robustness (reliability) 4) aesthetics (craftsmanship, cleanness, attention to the overall "spirit" of the device, etc.); 5) attention getting (interest, innovative, etc.) 6) the container (mostly aesthetics) and 7) operations manual. The Design Evaluation is worth up to 20 points.

The next "work session" is free, and the Final Report (worth up to 25 points) is due on in the fifteenth week. Each student also completes a peer evaluation of his/her teammates, and the individual grade for the team project may be raised or lowered based on this feedback as well as the instructor's semester-long observations.

Objectives and Considerations for the Major Team Project [1]

The objectives of the major project are:

- to provide an opportunity to practice design,
- to provide an early focus on design in the curriculum,
- to demonstrate aspects of engineering, e.g., team building, planning, scheduling, communicating (orally, written, and pictorially), constructing, and selecting materials, that many in the class have not yet experienced,
- to provide an opportunity for a directed, cooperative team activity,
- to allow students to experience the potential difficulties and rewards of working in a team environment,
- to encourage community building among class members by having them experience a common problem,
- to urge students to better appreciate the values and skills of others, including technicians and craftsmen (skill diversity appreciation),
- to help students to recognize the need for the assessment of available resources and skills within the team to assure success and reduce cost,
- to stress the importance of effective written, oral and graphic communication in expressing and conveying ideas both inside and outside of the team, and
- to have fun, and most do.

Issues associated with the formulation and conduct of the Major Team Project are:

Constraints and Goals: In separate exercises the students learn about design constraints and design goals [2]. The preparation of detailed "target" specifications in the early design phase are practiced. As part of the documentation of their projects, the teams must prepare design specifications that clearly distinguish the difference between the "required" and the "desired" features of their devices. It is stressed that devices must satisfy all constraints and a figure of merit is developed which provides a quantitative measure of the closeness of the approach to the various goals.

Team Formation: Some design educators think that team membership should be determined randomly, while others argue that an effort should be made to create teams of equal capability. Some believe that students could be teamed with peers on their own academic level in order to minimize frustration and keep the workload in balance, or with peers of compatible personality using the results of psychological testing such as the Myer-Briggs test (more on Myer-Briggs later). Some believe that students should be free to select their co-workers. Most of our students work either full or part time and do not live near the University. In a city as spread out as Houston, relative geographic location of team members can be a determining factor in the success or failure of a team. Long commutes and/or lack of reliable transportation can be serious disadvantages. In this class students choose their co-workers or are put into a pool for random team formation. (Few place themselves into this pool.) Since most of the students enrolled in the class have had no previous engineering courses, they rarely know their classmates. Therefore the student presentations on the second day of class (as previously noted) are important in providing an opportunity for the students to get to know each other.

Team Size: The optimal team size has been an issue for many instructors. The first time the author taught this course, the students were given the opportunity to form teams of any size up to four members. There were 45 students in the class and over 22 teams were formed. Several were one-person "teams". It is clear that many students do not want to work with a team. Each semester some students still request to work alone. Request denied! Teams of four have worked well. Six is definitely too large; two is definitely too small. One of the interesting benefits of the team projects, i.e., forcing students to work with strangers, is that many good relations are developed. Teams formed at random in the design class are seen working together in other classes and are commonly teamed together in the senior design course two or three years later.

Varying Skill Levels: One of the most difficult issues associated with a design class requiring the construction of a device is the significant differences in the students' technical backgrounds, primarily construction skills and mechanical ability and knowledge. Surprisingly, a significant percentage of the students has had no exposure to basic hand tools or even to readily available materials, while others have access to and experience with well equipped machine or wood shops. Typically, twenty per cent have extensive machine shop experience; half of those currently working as machinists. Although knowledge of construction is essential to designers, the already overloaded engineering curriculum does not allow for extensive shop training, and students are thus expected to acquire some of these skills outside of class. These issues give rise to resentment on the part of some unskilled students who feel that they are put at a competitive disadvantage. More mature students recognize their weaknesses, team with students who complement them, and learn by the experience. In good teams, knowledge is shared among team members. The importance of a realistic quality assessment of the available resources and skills within the team is essential. Many of the more successful teams had limited resources, but were able to recognize this weakness and compensate by being extremely creative. As noted previously, a small work area is available to the teams.

Spread the "Pain": A difficulty can arise in the design class when a team produces an unsuccessful device or no device at all even though it is clear that considerable effort has been expended. So that the grade for the project does not rest solely on the success of the device at a given time and place, the grading is spread out over the entire semester: progress reports, final written report, final oral report, test of concept, final test (competition), and an overall evaluation of the device after it has been demonstrated to perform satisfactorily.

Discourage Last Minute Construction: Clearly, last minute activity is a fact of design life. However, requiring the Initial Test or Test of Concept (in the seventh week) is an attempt to force the students to gain an appreciation of the difficulties of fabrication at a time when they can still profit from their mistakes. The Initial Test is a greatly simplified version of the Final Test given on a pass/fail basis and unsuccessful teams have additional time to retest. Hopefully, lessons learned will be carried over to the Final Test which is usually a high stress time.

Design for Assembly: For the last eight years devices have been required to be initially confined in a relatively small container which the students build. The teams are given a limited "set up" time, typically three to five minutes, to deploy their devices. The containers are also judged. The main reason for restricting the size of the undeployed devices was to reduce the size and extent of the deployed device. The volume and weight constraints greatly increase the creativity necessary to be successful.

Compete against the Clock: There is no "head-to-head" competition. Each team competes against the clock and the ruler. The performance requirements are carefully stated as "constraints" (the absolute limits in time, size and weight) and the "goals" (shortest time, smallest size and minimum weight). Credit is given on an absolute scale for satisfying the constraints, and on a relative scale, i.e., relative to other teams, for close approach to goals. The absolute scales relieve some of the pressure on the students but greatly increase the pressure on the instructor to define realistic requirements.

Limited Operator Participation: Automatic control or remote controlled devices would normally be preferred in a design competition. However, such devices require a level of sophistication (not to mention the expense) that is not reasonable to expect from beginning engineering students. There have been projects in the past in which "operators" were allowed a physical presence (mechanical controls, etc.), and they can unfortunately play a role in the success of the device by overplaying and/or "forcing" the device. Operators seem to find a way to use their device in an unintended manner "in the heat of battle." For example, joints restricted to a single degree of freedom by the rules are sometimes forced to multiple degrees of freedom by an anxious operator. Likewise, structural failures may be "supported" by the operator in a manner not intended. These actions are difficult to control much less evaluate fairly. Therefore, the "operator" role is carefully defined, usually limited to a simple "release" at the beginning of the run.

Written Reports: Two written progress report and a final report are submitted. No specific format is required, but information is made available on report writing and the format possibilities are discussed in class. A list of topics to be covered in the progress reports and in the final report are provided. The reports themselves are viewed as design projects (a problem to be solved). Reports are read carefully and significant feedback on content and style is provided, especially in the first progress report. The reports are to contain or address: letter of transmittal; title page; abstract; table of contents; logs of team meetings; plans; schedules; how have plans changed and why; how the work is divided among team members; neat and proper graphics; properly referenced tables, figures and equations; proper use of appendices and conclusions. Errors noted in the initial reports are expected to be corrected in subsequent reports. All previous reports are submitted as appendices to the current report. Careless writing and errors in grammar are not tolerated and considerable effort is made to correct all errors and, if necessary, to provide references to the University's Writing Center.

Oral Reports: Each team makes a "final" twenty-minute oral presentation to the class. Well organized and rehearsed formal presentation are encouraged. But originality and creativity (in good taste) are also rewarded and teams are encouraged to be "entertaining". Both the team and the individuals are evaluated, with each person receiving written comments. The presentations are approximately two weeks after the Final Test and changes and improvement in the devices are allowed, in fact, encouraged in the two-week interval. During this presentation, the team must demonstrate its device satisfies all constraints, i.e., is successful. After the presentation all "successful" device are evaluated.

Team Monitoring: Each team meets with the instructor at least twice prior to the Final Test and presents an informal oral report on progress and difficulties. The instructor questions each team member. The teams are also asked to report on any "dysfunction." These meetings have proven to be very helpful in identifying potential problems and increasing the quality of the students' work.

Personality Issues: A "lay" version of the Myer-Briggs temperament evaluation has been administered to the class each semester for the last thirteen years. An interesting and very consistent class profile has evolved [3]. In any event "diversity" is discussed in light of the results for the class. Teams are not formed based on these results. However, individual differences are discussed in hope that it will help team members to better understand how to interact with each other.

The Devices: The major concern for the course is safety. As a result, projects are selected to minimize the potential for injury to the students during the construction and the performance stages. In the 1980's there were several student injuries related to the accidental release of powerful springs. Power for the projects is now usually limited to that derived from gravity. Occasionally small battery operated motors are allowed, but the motors are usually less than effective since they must be controlled automatically and gear boxes must be fabricated by the students. For the most part the devices must move something(s), e.g., baseball, softballs, golf balls, ping pong balls in a prescribed matter. The objective in the Final Test is to provide a device that satisfies all the constraints, e.g., the device must be deployed from a six-sided container whose longest edge dimension is less than two feet, must weigh less than five or ten pounds (depending on the requirements), must perform the prescribed task in the given time window and in a specified space (a parallelepiped whose base is 30 inches by 60 inches and is 36 inches high), must be deployable and operational in five minutes, must have been constructed by members of the team without the use of any prefabricated "systems" although components such as gears (but not gear boxes), hinges, pulleys, wheels, bearings, and shafts are allowed. In addition, the device attempts to maximize a figure-of-merit function that prefers devices that most closely achieve a set of goals: minimal weight, minimal size of the container that the device is deployed from, minimal difference between the specified time and actual time for the task, and spend less that $50.

Example of a Major Design Problem Statement (from Fall 2003: paraphrased from an eleven-page document)

Each team will design and fabricate a structure and all the auxiliary systems (hereafter called the "device") to transport sequentially at least two, but up to ten, ping pong balls to a height of at least twelve inches before depositing them in one second or longer intervals into a provided container, within 30 seconds in a limited space and without operator intervention. The device will operate on top of a table provided by the instructor. The device shall weigh less than five pounds and shall be deployable from a six-sided container with each edge length less than 19.0 inches (corresponding to the cube of volume 4.00 cubic feet). Both the device and the balls shall remain at all times within the space above the plane of the top of the table and not higher than 24 inches above the table, i.e., within the parallelepiped whose base is the table top and whose height is 24 inches. Gravity is the preferred prime mover but any source of energy may be utilized as long as it is self-contained (e.g., batteries) and counted as part of the device. The above requirements must be fulfilled for the device to be "successful", but the goal is to maximize the figure of merit, FM, defined as

$$FM = (30 - \sigma) + 2\beta - 4\lambda + 3(5 - \mu) + 2(4 - \delta)$$

where

- σ is the total run time in seconds ($\sigma \le 30.0$).
- β is the number of balls successfully transferred ($2 \le \beta \le 10$).
- λ is the number of balls "dropped" during the run (not in the final or initial container or the device at the end of the run) ($\lambda \le 8$).
- μ is the weight of the device in pounds ($\mu \le 5.0$).
- δ is the volume (in cubic feet) of the container (actually the cube of its longest edge dimension) ($\delta \le 4.0$).

The performance of the device will be evaluated during three tests: the Initial Testing on October 6th, the Final Testing on November 3rd, and during the Presentation on November 19th. Overall design evaluations will be conducted after the Presentation on November 19th.

The Do's and Don't's for Major Projects

The Do's are:

- Limit the operator influence; if possible allow the operator only to "release", with no active force and/or limit the degrees-of-freedom of the allowable force vector input.
- Make the activity visible from a distance of about fifty feet so that audience interest is maintained.
- Emphasize esthetics for the devices and their containers. In the past teams have selected team names and the associate esthetics from an instructor given theme, e.g., the NFL teams, the NBA teams, the countries of the world, the states in the USA, etc.
- Take extreme care in writing the problem description. Let others review it. Try to anticipate all possible (mis)interpretations and make no grammatical/spelling errors (to set a good example and to establish a serious technical spirit).
- Clearly communicate to the whole class rule clarifications and revisions. Repeat profusely.
- Place expectations (a goal) on expenditures. Require an itemized expenditure list including the estimated cost of "donated" items. Teams are not penalized for overspending unless it is excessive.
- Give a lot of thought to what pre-fabricated components or parts will be allowed. Students will challenge all constraints and it is important to be consistent. Hopefully problems will be discovered early by monitoring the progress of the designs. It is a sad moment when a device constructed with an illegal component is discovered during the Testing.
- Stress that repeatability and robustness are important issues that are often overlooked.
- Require that each team develop at least three distinctively different concepts early in the design process. These should be reported and their relative merits discussed in the Progress Reports. Stress that "one idea is a bad idea" and that alternative concepts are important in case the primary design is unconstructable.
- Respect the effort of all students (who make an effort) even if the quality of their output is inadequate.
- Expect arguments and complaints. Avoid possible misunderstanding and inconsistencies in the writing of the assignment and spell out all rules and regulations in a clear and precise manner. The project description should be complete before distribution; anticipate problems if modifications or revisions are necessary.
- Insist on the fact that the instructor's interpretation of the rules prevail in case of controversy. The instructor is the client.
- Develop a scheme to penalize those who do not contribute to the team. Peer evaluations of team members are effective. There are at least two possibilities: relative performance of individuals (Student estimates the percent of the effort of each student on his team either individually (in secret) or as a team) or absolute performance [4].
- Make a big deal over the most successful designs. Attempt to develop a dedicated and prominent area in the Department for the display and recognition of them. Establish a tradition. Many students reveal early in the semester that their personal goal is for their design to be so recognized and displayed.

The DO NOT'S are:

- Do not expect the projects to be easy to manage.
- Do not schedule the Final Testing the last week of class. Complaints will come from students and colleagues alike.
- Do not expect too much. Normally two or three (of the ten to fifteen) teams with considerable fabrication experience "break the curve" by producing near perfect devices. On the other hand some teams will attempt to "get by" with cardboard and duct tape.
- Do not expect machine-shop quality nor professional esthetics. Actually, esthetics is usually the downfall of most otherwise good devices.
- Do not expect much interest from your colleagues. However, they are pleased that you are teaching a design course and they are not.

Discussion of the Major Project

This has been a brief overview of the philosophy used for and lessons learned from assigning a "major" team project as part of a sophomore design course for the past thirteen years. The students complain about the extra work of the project but generally appreciate the opportunity to work in a team, to create a device, to receive feedback on their design skills and communication efforts, and to receive recognition from their peers for their efforts. One would think that creating a new project each semester with little concrete evidence about whether or not the requirements will be impossible to meet, unreasonable, or trivial would be a serious concern. In fact, this uncertainty about whether half the course would be a failure was a large burden in the beginning. However, to this point each project has been at least a moderate success. There have been only two "failed" teams in thirteen years. The class drop out rate is less than 5% after the first two weeks.

A PROJECT WITH THE DEPARTMENT OF INTERIOR DESIGN IN THE ART DEPARTMENT

Six times since 1996, the sophomore mechanical engineering design class has met for about three weeks with an art class to work on projects together and to allow the students of both disciplines to better understand design. Three times we formed multidisciplinary teams to work on the particular project that is discussed in this section; twice with students enrolled in the introductory course, "Fundamentals of Interior Design" (Introduction to three-dimensional design theory) (spring 1996 and spring 1998), and once with students enrolled in "Intermediate Interior Design." (spring 2001). In the collaborative design experiences the teams were nearly all three-member teams with two engineering students and one art student. There were approximately 40 engineering students and twenty art students each time.

Different Skills and Attitudes

Engineering and art students approach the design "process" in different ways. Each group seems somewhat in awe of the other since each seems to possess a different set of skills and knowledge. Engineering students usually possess a higher level of analytical skills and of mathematics and science knowledge, but may be lacking in the ability to apply these skills and knowledge. On the other hand the art students possess skills lacking in most engineering students. Two will be noted here: the abilities to work with and evaluate qualitative information and to avoid fixation.

Processing Qualitative Information: Associated with ones ability to work with and evaluate qualitative information is the ability to give and receive criticism. Many engineering students are very uncomfortable with the public nature of criticism in the art classroom. They also have some difficulty adjusting to the "class as a team" concept in which all the art students freely interact offering suggestions to their "competitors." The engineering students tend to be generally secretive about their projects and are reluctant to become involved in the give and take atmosphere of the art classroom. Working with and evaluating qualitative information is at the heart of the creative process, and people in engineering do process this information differently from artists. This difference could be attributed to the different nature of their educations and/or to the fact that they long ago chose a career path that emphasized quantitative processes (the engineer) over the qualitative processes (the artist) or vice versa. In any event, one characteristic of a good designer is the ability to generate many alternatives (brainstorm) and then evaluate. ("One idea is a bad idea.") Sometimes the generating and selecting process is interrupted by fixation.

Fixation: Fixation or functional fixedness is associated with the premature commitment to the solution to a problem. In the case of designers these early design decisions are usually represented by the adoption of an idea or form previously developed. This fixedness can take two forms: an inability to recognize that better solutions may be available or an inability to recognize that solutions to other problems could be successfully adapted to the current problem. Reference [5] discusses the issue of fixation as related to whether or not its presence in a designer could be related to his/her education process. A series of experiments is described in which groups of mechanical engineering students and groups of industrial design students worked on several different types of design projects. Some of the groups were "accidentally" supplied with information on good or poor potential solutions. The final designs produced by the groups were evaluated and analyzed to determine what effect if any the "leaked" information had on their results. It was concluded that engineers (whether by nature or by education), tend to be less creative in that they prefer an iterative or variant design approach, i.e., used the "leaked" solution, with the result that they are less likely to develop "break through" designs. On the other hand, the industrial designers seem to ignore any existing solutions and seem determined to strike out on their own.

Different Personality Types

There are few groups that are more different than engineering and art students as illustrated by the noting that the engineering students were 82% male while the art students were 81% female and by examining Tables 1 and 2. These tables summarize the results of applying the Keirsey Temperament Sorter [6] to both populations to determine the Myers-Briggs Type Indicators. The numbers presented in the tables are the averages for thirteen years of the engineering classes (approximately 1200 students) and for the students in the three art classes (approximately 50 students). The concept of personality preferences was developed by Jung in the 1920s and then rediscovered in the 1950s and put into practice by the mother-daughter team of Katheryn Briggs and Isabel Myers. The basic premise is that ones personality can be characterized by how one rates on four continuous scales, the end points of which are depicted in Table 3, e.g., E and I. An important point is that most people are neither one extreme nor the other, but, for example, only extraverted or introverted to some degree. Jung also felt that these preferences could change or could become stronger with time. Table 1 presents the personality preference for both groups and for the general population. Note that the art students tend to be strongly Intuitive (opposite of S) and very strongly Feeling (opposite of T) compared to both the engineering students and the general population. The four preferences taken together create sixteen possible Type Indicators as illustrated in Table 2. Only those type indicators for which either the art or the engineering students comprise 10% or more are shown in Table 2. Seventy-nine per cent of the art students are confined to four of the sixteen possible Type Indicators. It turns out that sixty-one percent of the art students were NF compared to 17% of the engineering students. The engineering students are not bunched quite as much, but still 60% of the engineering students were TJ compared to only 6% of the art students.

Jungian Preferences (See Table 3)	**E**	**S**	**T**	**J**
Art Students	70	32	12	68
ME Students	64	58	70	84
General Population	75	75	50*	50

*60% for males, 40% for females

TABLE 1
PREFERENCES FOR ART AND ENGINEERING STUDENTS (IN %)

Personality Types	**ISTJ**	**INFJ**	**ENFP**	**ESTJ**	**ESFJ**	**ENFJ**	**ENTJ**
Art Students	2	15	25	1	18	21	1
ME Students	17	4	5	24	7	8	12
General Population	6	1	5	13	13	5	5

TABLE 2
MYERS-BRIGGS TYPE INDICATORS FOR AT LEAST 10% OF EITHER GROUP (IN %)

E	**Extraversion** external, interactive, sociability	vs.	**I**	**Introversion** internal, concentration, territoriality
S	**Sensation** realistic, perspiration, past	vs.	**N**	**Intuition** speculative, inspiration, future
T	**Thinking** objective, impersonal, justice	vs.	**F**	**Feeling** subjective, personal, humane
J	**Judging** settled, fixed, closure	vs.	**P**	**Perceiving** pending, flexible, open options

TABLE 3
JUNGIAN PAIRS OR PREFERENCES

The Project

The project was to develop, fabricate, package for sale, and promote a "Chindogu". Chindogu is taken from two Japanese words, 'chin' meaning unusual and 'dogu' meaning tool. Chindogu refers to a gadget that appears to be useful but on closer examination is not. These gadgets must exist, but they cannot serve a reasonable function. There are several websites [7-11] that provide more details and examples. The ten tenets [8-10] of Chingodu are:

- A Chindogu cannot be for real use.
- A Chindogu must work
- Inherent in every Chindogu is the spirit of anarchy.
- Chindogus are tools for everyday life.
- Chindogus are not for sale.
- Humor must not be the sole reason for creating a Chindogu.
- Chindogus are not propaganda.
- Chindogus are never taboo.
- Chindogus cannot be patented.
- Chindogus are without prejudice.

Over an hour is devoted in the class to discussing the idea of the Chindogu and the discomfort that most likely is associated with designing and fabricating one, especially for the engineering students who are being challenged in a different way. But then the Chindogu project is intended to upset the engineering students by confronting them with an unfamiliar situation in which uselessness and humor are desired, not the usual engineering design goals. Example Chindogus are shown and discussed in class. These demonstrations are not to give students specific ideas (although many engineering student seem initially satisfied to start there, i.e., copying), not rather to jar them emotionally and to sanction the idea of playful thinking. Students are encouraged to use their own life and daily routine as sources for ideas.

The Critique Method [12]

Perhaps the most important part of the exercise for the engineering students is their (first) exposure to the critique method of design evaluation and improvement. At the midpoint of the project all teams bring their gadgets (such as they are at that point) to class for review by the class and the instructors. Normally, in a class critique all the class members gather around to observe. However, the normal art class size is 20 students, not 60; so students are encouraged to work on their projects during the traveling critique. Under these circumstances the critiques are primarily a conversation between the instructors and the team with about ten students in the area listening in and commenting. About a third of the gadgets are rejected by the instructors at this point based on violations of the tenets or a lack of good taste. Another third to a half are challenged as being "not good enough". These rebukes are shocking to the engineering students. Many respond with the classic statement, "Just tell me exactly what to do, and I'll do it." Of course, this response is exactly what we do not want to hear. We provide advice, even suggestions, for improvements but are careful to remind the students that these are their projects, and we expect more than what they are told to do. Many engineering students find the public humiliation of being told to do it again more troubling than the extra work. In fact, we have had engineering students refusing to take part in the process. On the other hand, the art students normally carry the day by intervening with additional help for teams that are struggling.

Packaging and Promotion

Packaging and promotion are not part of the Chindogu process, but something that we added as a way for the students to demonstrate the apparent "realness" of their gadgets. Students are encouraged to develop creative packaging schemes along the lines of actual products. They are told to study the way products are displayed in the stores and copy the ideas, e.g., packaging designed to hang from brackets, including bar codes, web addresses (some even develop actual web sites), and contact information. We encourage two possible modes of promotion: a videotape or a live performance mimicking the normal commercial or an infomercial. Most are satisfactory, but we are usually pleasantly surprised by several complex productions. Some of the videotapes contain campus interviews and testimonials. Many are well produced with voice-overs, music, and other sound and video effects.

Some Results

The websites listed above have dozens of creditable Chindogus, and many students claim that they were inspired to their own Chindogu by reviewing these examples. However, other students appear to have followed our advice and simply paid attention to the world around them and came up with completely new ideas. Some of them are illustrated in Figures 1 to 4:

Sani-Wrap, Figure 1**:** Everyone knows that paper towels get soggy and torn and are then unusable. We also know that we can in some instances reuse a paper towel. To address this limited reuse feature why not design a supplementary product to extend the life of paper towels. If the paper towel is encased in a protective plastic bag, e.g., a ziplok® bag, then it will remain in its original pristine condition and will be reusable for an extended time. However, the towel is now useless for its intended purpose. So in solving one problem, we have created another.

Mommy Moo's Milk, Figure 2: In some households it is common practice for all family members to drink directly from the liquid containers in the refrigerator. This practice may be offensive to guests who occasionally require drinks, and even though their refreshment may be served in a glass, the image of the activities of the previous users may be troubling. Mommy Moo's Milk is now available with multiple, built-in, color-coded nipples so that each family member can have his own assigned spout.

The 3800 XL Tooth Paste Opener, Figure 3: Many people have had to face the embarrassment of a dirty mouth all day because they didn't have the strength to open their tube of tooth paste in the morning. No more. The New 3800 XL electric tooth paste opener is now available at drug stores everywhere.

Elegant Evening Sundials, Fig, 4: What could be more elegant that a beautifully crafted, black sundial to match ones black formal evening attire?

Other student-developed Chindogus are listed below:

A TelStar system to find lost twisty ties: Simply attach the signaling device to each of your twisty ties as you place them in the drawer. The device comes with a magnetized pad with the 800 number to call should you be unable to locate one of the ties. The magnetized pad can be placed on the refrigerator door.

The RodoWheel stirring device: Many recipes require constant stirring that of course is very frustrating for someone in the middle of preparing a meal. The new RodoWheel is a deep pot with a built-in "squirrel cage" that extends to near the bottom of the pot. You may insert the rodent of your choice to keep the cage turning and your food well stirred.

The engine oil recycler: A small pan that is mounted below an oil leak under your car. Every night you simply jack up the car and remove the pan, pour the contents into the oil reservoir and replace the pan under the car.

Tanning oil: SunBlock with a negative sun protection number

Glasses wipe: Eye glasses fit with tiny wipers controlled by a mechanism actuated by the person's jaw. So by opening and closing your mouth, your glasses are cleaned. (This device was built and actually worked!)

Strapee: Various hairpiece accessories (several "wigs", side burns, mustaches, and beards) with Velcro backing that can be attached to a skin-tight Velcro head bag. The idea is rather silly but their infomercial could have played on Saturday Night Live.

Drink-a-Ball: A set of balls, e.g., football, soccer ball, etc. into which a small plastic bottle had been imbedded. The opening of the bottle extended through the surface of the ball and was closed with a cap. The bottle could then be filled with the drink of choice and be available during play. The idea does not sound so great, but they did a great job fabricating the devices and then demonstrated that the device actually worked.

Discussion of Chindogu Projects

The Chindogu project has also been run twice in the sophomore design course without the art class. While it is not possible at this point to provide a quantitative measure of the relative quality of the results between the combined classes and the engineering class, my impression is that the combined classes did a better job on at least three accounts:

- Generally the ideas were more "believable" (Tenet #4: Chindogus are tools for everyday life.) and in better taste (Tenet #8: Chindogus are never taboo.)
- While the fabrication possesses were not distinguishable, the esthetics on the Chindogus were definitely better for the combined classes.
- The packing was much more interesting and believable for the combined classes.

Traditional engineering design projects tend to be rather predictable and practical and don't encourage "wild thinking" since in the end they are for a real purpose, and frankly engineering students are not likely to develop any revolutionary designs. However, in the fanciful world of the Chindogu, the practical harness is off, and students are free to be truly creative without fear that the bridge will collapse. Engineers prefer linear thinking and rational processing, and that way of thinking is what is prized in the engineering education. The Chindogu takes the engineer out of his comfort zone, and his success under awkward circumstances generates confidence.

FIGURE 1
SANI-WRAP

FIGURE 2
MOMMY MOO'S MILK

FIGURE 3
3800 XL TOOTH PASTE OPENER

FIGURE 4
EVENING ELEGANCE SUNDIAL

CULTURAL DIFFERENCES IN DESIGN

Introduction

The world's economy and industries are becoming increasingly global. But it spite of the globalization efforts in economic, industrial, and financial circles, engineering instructors rarely implement international collaborative efforts in teaching and seldom know how programs operate in foreign countries. Of course, many institutions offer selected students opportunities to study or even work abroad, but these international experiences rarely benefit the entire student body. International collaborative experiences in teaching can be beneficial to both instructors and students. They may acquaint instructors with new teaching tools and methods, provide valuable data regarding differences between student populations and eventually provide answers on discrepancies between engineers' behaviors and competitiveness in the workplace. Students would undoubtedly benefit from such experiences by widening their understanding of foreign countries and associated cultures. The acquisition of such knowledge is particularly important in the context of international design practice. This section describes the implementation and results of a design project developed and offered jointly by design instructors at the University of Houston (Texas, USA) and the Kanazawa Institute of Technology (Ishikawa, Japan). While this project is a very small step towards international collaboration and information exchange, it demonstrates a cultural "disconnect."

The Participants

The Kanazawa Institute of Technology (KIT) [13] is Japan's largest institution of higher learning specializing in engineering and technology. A new sophomore level, two course sequence in engineering design was introduced as part of a new curriculum launched in 1995 in an effort to promote the integration and application of acquired knowledge and skills. The main objective of this new sequence was to provide students of all engineering majors with a first opportunity to experience and implement the design process. This design experience and their newly developed understanding of some of the methods and tools available to designers were expected to enhance the students' ability to solve open-ended (and often ill-defined) problems in real life settings. Each course requires the students to participate in a quarter-long team project (typically involving the rethinking and redesign of a real life artifact) from the problem discovery stage, to a problem statement, and eventually to the detail design stage. Most teams (composed of five or six students) work on different projects as each problem statement is derived from the teams' findings at the problem discovery stage. Most students entering this two-course sequence have had no previous experience in design as the Japanese high school educational system emphasizes knowledge acquisition with little consideration for applications and open-ended problem solving. The typical KIT sophomore student is twenty years old and finished high school two years prior to his/her enrollment in the first course of the sequence. An average of two thousand students enroll each year in each of these two core courses. Ten to twelve equivalent full time faculty members, of both Japanese and foreign origin, coordinate their efforts to develop and teach the courses. The lecture time is principally used to provide guidance to the students relative to the design process and to introduce design tools and methods.

The courses at KIT and UH share some common points. In both courses, students perform significant design work as they are required to not only conceptualize but also finalize their solutions. Both student bodies exhibit a clear lack of design experience as they enter the course although the more heterogeneous UH students tend to have some industrial experience and access to personal or company tools, equipment and work space. KIT students mostly live in student housing and have no industrial experience. In both courses, emphasis is put on the use and application of skills rather than on the acquisition of knowledge. Most of the learning is achieved through doing and a large percentage of the course content is therefore allowed to vary. In both courses, appropriate feedback and support are given to the students during their design journey but no "recipes" are provided. Students are encouraged to explore and make mistakes. In summary, the differences between courses can be found in the level of homogeneity in the two student bodies, the more restrictive time constraints imposed on the Japanese course (The KIT academic year is composed of three ten-week "quarters" while the UH has two thirteen-week semesters.), the population size, and the access to personal tools and equipment.

Project Description

This project involves the design and fabrication of a low-cost device whose main purpose is to support a set of chopsticks while not in use (i.e., a chopsticks rest or haski oki, in Japanese) during a meal for the Japanese market. This project was introduced in the first week of the Fall 1997 offerings of both the US and Japanese design courses [14]. In both countries the instructors provided only minimal guidance to afford the engineers-to-be with a first brief experience in design before they had to tackle their major project for the semester. The project and the associated results were used during the remainder of the course to explain good versus poor design practice by example. The forty American students were asked to submit their results individually. In Japan, the instructing team opted for team submissions because of time constraints. The project was assigned to teams of five and six members across the twelve sections (a total of four hundred students). The time allotted to the project was one week in Japan and two weeks in the USA.

Existing Solutions and Table Manners [15,16]

Before examining the students' submissions, it is useful to introduce some of the existing solutions and to discuss Japanese table manners. Chopsticks are used in most parts of East Asia to prepare and eat food. They are available in a variety of lengths and materials. Japanese chopsticks are the shortest of all and are typically made of wood. Chopsticks holders are commonly used in Japan and come in many shapes, materials and sizes. Their purpose is to prevent the end of the chopsticks that comes in contact with the food (referred to as the active end or tip) from coming in contact with the tabletop. They should also allow the user to easily pick up his/her chopsticks from their position and serve as ornaments.

The Japanese etiquette for chopsticks' usage is strict. Formal etiquette requires that chopstick be picked up with thumb, forefinger and middle finger of the right hand at their center. The left hand is then used to provide support so that the right hand may be repositioned under the chopsticks for proper use. Placing the chopsticks back on the table involves the reverse operation. The chopsticks should be replaced on the holder when not being used. The following practices: (a) stabbing food with chopsticks, (b) breaking food items using one chopstick in each hand, (c) passing a food item from one set of chopsticks to another, (d) moving tableware with the chopsticks, (e) hitting the table or tableware with the chopsticks, (f) planting chopsticks vertically in rice or any other food (This is done only when offering food to the dead.), (g) licking the chopsticks. (h) mismatching the chopsticks, (i) inserting the wrong end of a pair of chopsticks into ones mouth, (j) using chopsticks as toothpicks, (k) placing the chopsticks across a bowl or plate when not in use, and (l) using the chopsticks with the left hand (even for left handers), are all considered unacceptable, rude, and/or unrefined. American students were not necessarily aware of some of these unofficial rules and therefore created some ill-fated artifacts. Conversely, the creativity of the Japanese students might have been stifled by their desire to adhere closely to these guidelines.

Selected American Solutions

A selection of models produced by the American students is presented and evaluated below. The reader may find that the comments provided here tend to stress the negative aspects of the proposed solutions. The intention is to demonstrate the importance of integrating cultural factors in the practice of design. A designer's lack of understanding of (or respect for) cultural and traditional values may predestine his/her creations to commercial failure. The American students were very creative as 90% of the devices were original creations significantly different from the current solutions. Also, craftsmanship was exemplary.

The two systems, shown in Figure 5 and 6, were designed to hold a napkin and a pair of chopsticks. While the designers should be praised for attempting to design bifunctional systems, they should also be reminded that their products would fail in Japan. Japanese people rarely use napkins made of fabric as their multiple and repeated uses contradict with Japanese views of hygiene. They favor disposable paper napkins on all occasions. The system presented in Figure 5 forces the chopsticks to come in contact with the napkin and the napkin holder therefore leading to the contamination of the latter once the chopsticks have been used. The position of the chopsticks in both designs is unsatisfactory. Chopsticks should be presented parallel to and touching each other. In Figure 6 the chopsticks should be supported closer to the end that comes in contact with the food. The position of the chopsticks in Figure 7 is unacceptable on a Japanese table. The active tips should not point in diverging directions.

The systems presented in Figures 8 and 9 represent attempts to combine carrier and holder. Again, this honorable effort to attain multi-functionality produced mixed results. While both systems are esthetically pleasing, they do not correspond to the preferences of the Japanese population who typically do not put their carrying box (hashi bako) on the table and do not spoil it by placing "dirty" chopsticks in or on it. The system shown in Figure 9 would also prove to be difficult to clean if the tips of the chopsticks that come in contact with the food were to be placed in the housing during the meal. While the esthetics appeal of the two systems presented in Figures 10 and 11 is debatable, they present the advantage of positioning the two chopsticks together. Unfortunately, the tips that come in contact with the food are lodged into a closed housing where the food and fluids may accumulate during the meal. The orientation of the chopsticks (active tip down) is also unnatural for the Japanese population. However, these two receptacles could be used to hold chopsticks prior to the beginning of the meal. The disposeability of the housing shown in Figure 10 makes the associated model more appealing to the Japanese population. The models presented in Figures 12 and 13 keep the two chopsticks apart making them difficult to pick up. They both contact the active ends of the chopsticks. The chopsticks are required to pass through small holes in the holder in Figure 13. As a consequence food may collect around the edges of the holes during the process. The chopsticks' orientation is also unnatural as described earlier. The pyramidal holder shown in Figure 14 is a very distinctive solution despite separating the chopsticks. The L-shaped holder shown in Figure 15 could be commercialized in Japan. It respects the guidelines set earlier. The toothpick placed in the groove at the edge of the L is a nice addition. The model shown in Figure 16 offers interesting esthetics without failing the cultural test.

FIGURE 5
US SOLUTION WITH NAPKIN

FIGURE 6
US SOLUTION WITH NAPKIN

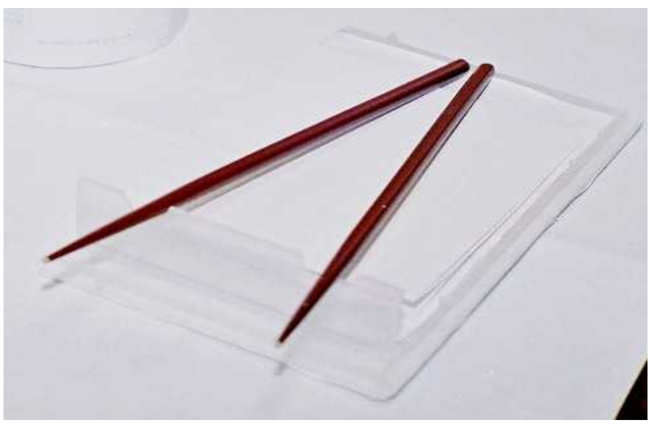

FIGURE 7
US SOLUTIONS WITH DIVERGENT CHOPSTICKS

FIGURE 8
US SOLUTION WITH CARRYING CASE

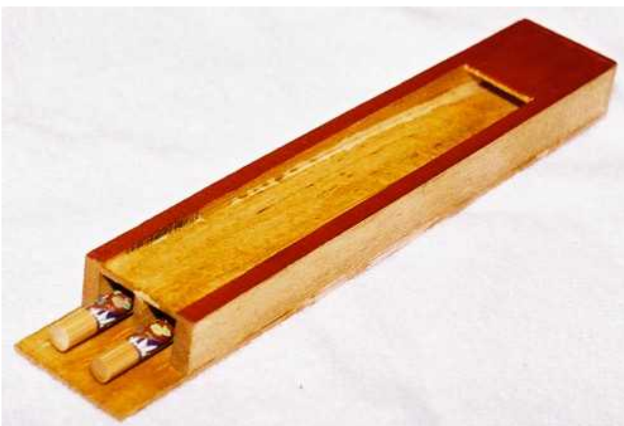

FIGURE 9
US SOLUTION WITH CARRYING CASE

FIGURE 10
US SOLUTION WITH A DISPOSABILITY AND AN ORIENTATION PROBLEM

FIGURE 11
US SOLUTION WITH A HYGIENE AND AN ORIENTATION PROBLEM

FIGURE 12
US SOLUTION WITH A PICK-UP PROBLEM

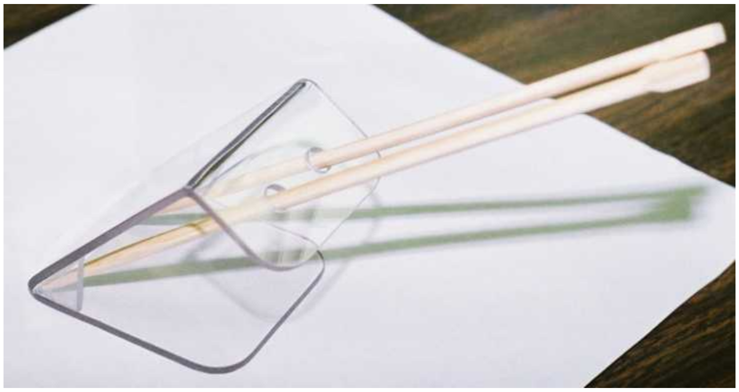

FIGURE 13
US SOLUTION WITH A PICK-UP AND HYGIENE PROBLEM

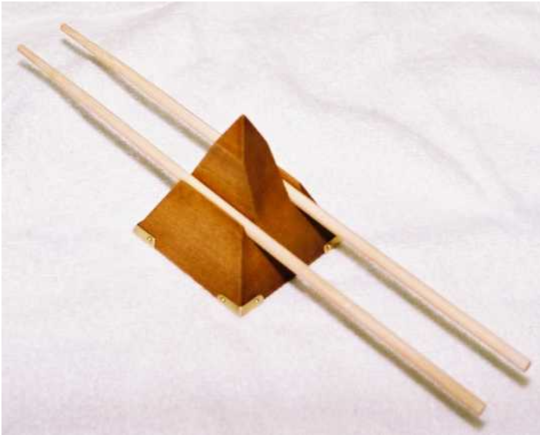

FIGURE 14
US PYRAMID SOLUTION

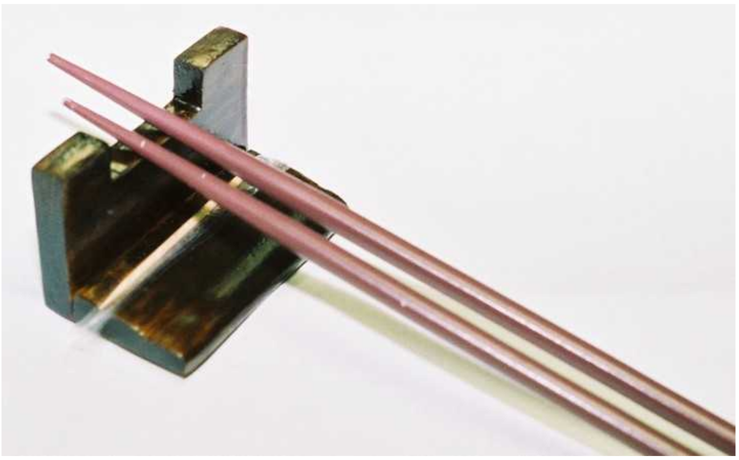

FIGURE 15
US SOLUTION WITH COMMERCIAL POSSIBILITIES

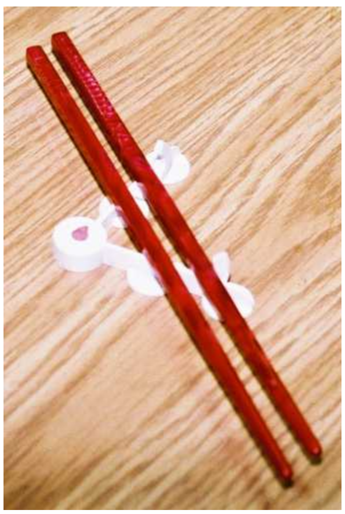

FIGURE 16
US Solution with Commercial Possibilities

The Japanese Solutions

A total of seventy-two designs were submitted by the Japanese students. Figure 17 illustrates one of the ten or so designs based on origami (paper folding). The art of origami is extensively documented in the literature and numerous designs are available already. Japanese students rarely attempted to achieve multi-functionality and concentrated principally on recycled materials and/or recycleability. Many designs were remarkably simple and inexpensive, e.g., a peanut or a piece of bamboo. About twenty design made use of recycled items, such as the bottom from a soda bottle or a wine bottle cork; many were very similar to the "common" Japanese designs, illustrated in Figure 18. These concepts lead to the creation of ill-fated products due to questionable esthetics. A number of holders were constructed from recycled chopsticks as well as from many other "found" materials such as wire and pieces of plastic. Two of the Japanese designs were in the form of a "pen holder" which held the chopsticks upright and would lead to food residues being left in the holder, thus violating two of the "best practice" tenets. Maybe these two represented the only "out of the box" Japanese thinkers.

Discussion of Cultural Influences in Design

American and Japanese sophomore engineering students were asked to work of the same short design project, namely to design and build a chopsticks' rest (a system to support two chopsticks while not in use during a meal) for the Japanese market. The product to be designed, while foreign and mostly unknown to the US students, is very well known and deeply traditional in Japan. Most American students attempted to design original multi-functional devices, but most failed to integrate cultural factors into their design thinking thereby creating holders unsuitable for the Japanese market as they violated some of the guidelines of proper table etiquette. Many Japanese students encountered difficulties in escaping the traditional representation of a chopsticks holder and in being creative within the boundaries of the cultural constraints. Students successful in this quest for novelty provided an original treatment of the product esthetics and/or addressed recycle-ability issues. This short collaborative project was a positive experience for both students and instructors. It provided an opportunity for the American students to expand their horizons beyond their national borders and emphasized the important of studying and acquiring an in-depth understanding of the target market. It forced the Japanese students to question an established and unquestioned solution to an old problem. Furthermore, both groups benefited from a study of the solutions generated by their foreign counterparts.

This design experiment has demonstrated that even the simplest of consumer products can fail due to cultural differences and barriers. The project can be repeated (serving as a case study for design classes) to demonstrate how the lack of knowledge and understanding of the cultural differences between societies can lead to unsuccessful products even if the project is a technical success.

CONCLUSIONS

It's never too early to start designing. In many engineering academic programs the introduction of design has been left to the very end when it was felt that the analytical tools necessary for "engineering" design would be available. However, there is much to learn and experience about design without the need for "engineering tools" as experiences in freshman and sophomore courses has been recently demonstrated in many undergraduate programs. (The sophomore design course described in this paper was first introduced in 1981.) However, design projects should be interesting and do require close attention by the instructor.

REFERENCES

[1] Richard Bannerot, "The DO's and DO NOT's for Major Projects in an Introductory Design Course", Proceedings of the 2002 ASEE Annual Conference and Exposition, June 16-20, 2002, Montreal, Quebec, Canada on CD.

[2] Richard Bannerot, "An Exercise in Problem Definition in an Early Design Course," Proceedings of the 2003 ASEE Annual Conference and Exposition, June 22-25, 2003, Nashville, Tennessee on CD.

[3] Richard Bannerot, "Identifying Psychological Diversity – the Use of a Myer-Briggs Type Indicator in Promoting Better Group Function," *Proceedings of the 1997 Annual Conference* of the ASEE Gulf Southwest Section, March 23-25, 1997, Houston, Texas, pp. 87-90.

[4] R. W. Brown, "Autorating: Getting Individual Marks from Team Marks and Enhancing Teamwork," 1995 Frontiers in Education Conference Proceedings, Atlanta, GA, November 2-4, 1995, available at http://fie.engrng.pitt.edu/fie95/3c2/3c24/3c24.htm, last accessed 12 August 2004.

[5] A. T. Percell, and J. S. Gero, "Design and Other Types of Fixation or Is Fixation Always Incompatible with Innovation?" taken from "Design and Other Types of Fixation, *Design Studies* , vol. 17, pp. 363-383.
[6] David Keirsey and Marilyn Bates (1984). Please Understand Me: Character and Temperament Types, Prometheus Nemesis book Company, Del Mar, CA.
[7] http://www.pitt.edu/~ctnst3/chindogu.html, last accessed 12 August 2004.
[8] http://www.stim.com/Stim-x/0796July/Phenom/chindogu.html, last accessed 12 August 2004.
[9] http://en2.wikipedia.org/wiki/Chindogu, last accessed 12 August 2004.
[10] http://www.designboom.com/history/useless.html, last accessed 12 August 2004.
[11] http://www.uh.edu/engines/epi1460.htm, last accessed 12 August 2004.
[12] Paul Ruchhoeft, Richard Bannerot and Ross Kastor, "Adapting the Studio Critique to Large Capstone Design Courses Proceedings of the 2004 ASEE Annual Conference and Exposition of the ASEE, June 20-23, 2004, Salt Lake City, UT.
[13] http://www.kanazawa-it.ac.jp/ekit/, last accessed May 2004.
[14] Jean-Luc Herbeaux and Richard Bannerot, "Cultural Influences in Design," Proceedings of the 2003 ASEE Annual Conference and Exposition, June 22-25, 2003, Nashville, Tennessee on CD.
[15] http://www.japan-guide.com/e/e2039.html, last accessed on 12 August 2004.
[16] http://www.japan-guide.com/e/e622.html, last accessed on 12 August 2004.

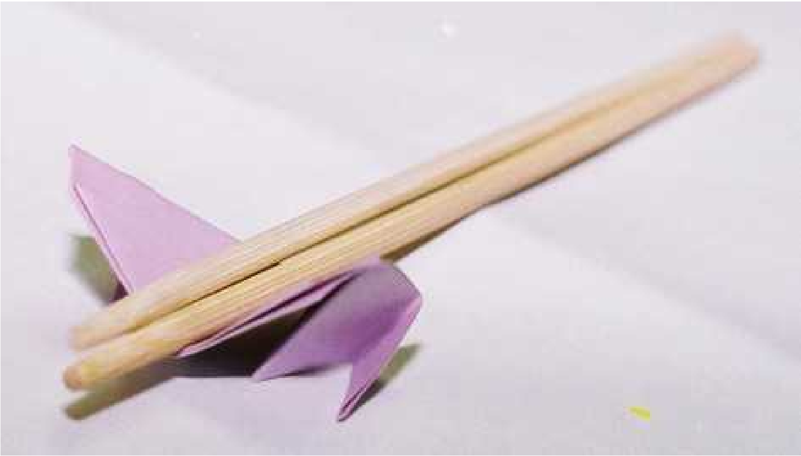

FIGURE 17
JAPANESE ORIGAMI SOLUTION

FIGURE 18
JAPANESE COMMON SOLUTION