Design for Effective Teaching and Learning in Technical Education

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ABSTRACT

We talk of design of a product for its strength, manufacture, assembly, recycling, product life cycles, etc. However, the methodologies used to teach these subjects are generally old-fashioned, for example, using a blackboard and one-way communication from a teacher to students. Only some cosmetic changes have happened in this process such as using an overhead or LCD projector. In fact, in many instances, the use of latter equipments increases the pace of the teacher, and makes the lecture more difficult for the students to understand. Also, the scope of two-way communication is greatly reduced. In order to overcome such situation the author has developed some teaching methodologies, which are full of fun. This paper explains how these methodologies can be designed so that they are effective in a classroom environment. It is hoped that such teachings will greatly enhance the students' interest in their courses, and make them more knowledgeable in those areas.

Key words: Design, Teaching, Learning, and Fun

1. Introduction

The word "Design" is used in engineering, fashion, product development, travels, and others. We do design a car-wheels' axle from the strength point of view so that it does not fail due to the loads coming from the road and other sources. One also does the design of a car's appearance, or a dress or furniture from the point of view how it looks. Alternatively, before we travel to a new destination, we design or plan the tour, i.e., how many days we stay, the mode of transportation to be used, the type of hotels we prefer, the places to be visited, and so on. What has just been explained is the meaning of design in different arena. There are also designs for different criteria. For example, the car's axle can be designed such that, in addition to its strength, it should have minimum deflection, maximum life, easy to manufacture and assembly, etc. In fact, the phrase "Design for X" is used to represent any new criterion X for the design of an element or system, be it an axle, shaft, electronic controller, car, washing machine, etc. (Huang, 1996). In a way, the topic of this paper can be categorized also as Design for X, where X stands for "Effective teaching and learning." The focus here is to introduce a new methodology for the classroom teachings.

Traditionally, in a classroom teaching didactic learning is used, i.e., a teacher lectures on the subject and the students listens. The teacher uses a blackboard to emphasize his or her points that are generally noted down by the students for future references. Since drawing a complex figure or writing a lengthy expression on the blackboard are time consuming, the teachers have started writing them on the transparencies before coming to the class. An overhead projector (OHP) is then used to display the materials on the transparency sheets. This mode indeed communicated the messages faster and better without any additional time than allotted for the lecture class, however, has the following drawbacks: 1) Since carrying an OHP to every classroom is not a feasible proposition, each classroom should be fitted with an OHP; 2) The use of OHP tends to increase the pace of the teacher, as he or she does not have to write on the blackboard; 3) The students do not have sufficient time not only to note down these drawings or equations for future references but also to think and grasp the subject. As a result, either the teacher should provide handouts or the students themselves should arrange them from the books the teacher is using. Doing this, there are financial implications to all parties, i.e., institute, teachers, and the students. Another practice in modern classrooms is to use a PC (personal computer) fitted with an LCD projector. Such arrangement, although suitable for the teacher to communicate his or her points clearly much faster through the use of an animation or software, is very expensive because the classrooms are now have to be fitted with the new equipments.

In all the three above modes of teaching, it is always the teacher who got a new tool to communicate, but not the students to interact with their teachers. Even if a teacher wants to enhance the student-teacher interactions, which is a two-way communication, he or she may not be able to implement it in larger classes of 80 or 100 students. Alternatively, reducing the class size to 20 or 25 students will increase the interactions, but is not acceptable to the administration due to

social obligation of educating a large mass together.

Realizing the shortcomings of traditional teaching methodologies such as those using blackboard or the OHP or LCD, there have been tools and procedures evolved over the years. For example, with the networking and IT revolutions, e-learning has become a buzzword. In the e-learning (Hamel and Ryan-Jones, 2003) web-based animations, texts, software, etc., are used to convey the concepts clearly which are otherwise not possible using the conventional blackboard or transparencies. This, however, requires networked classrooms. Due to the availability of the web-based information to the students even after the class hours, they can access and use them again and again. There do also exist other methodologies like those used in the design-oriented courses. For example, project based teaching and learning (Ridgeway, 1993; Gregson and Little, 1999). The author of this paper has also used similar concepts. Visits to automobile workshops, elevator rooms, etc., inside the institute premise were conducted for the students of Mechanical Engineering Design course to show them the actual components/systems that were taught in the lecture classes. Note here that the publications in the area of education, e.g., those appeared in the International Journal of Education and Arts, International Journal of Educational Technology, International Journal of Engineering Education, American Journal of Education, Australian Journal of Educational Technology, Global Journal of Engineering Education, in the international level, and the IETE Journal of Education, NCERT Journal of Indian Education, IISC Journal of Science Education (Resonance) in India, have mostly covered the articles on the new software developments for teaching, social impacts, education statistics, new science discoveries, etc. Almost no article could be traced on the methodologies that improve the two-way communication and generate increased interest amongst the students.

In this paper, a new teaching methodology is proposed, where "fun" is the keyword. Since any human being likes to have a fun either through a game or performance or otherwise, they have been incorporated here through three games. They have the following advantages: 1) Due to the fun elements in the teaching process, the subject becomes interesting; and 2) Two-way communications are achieved. The paper is organized as follows: Section 2 presents the philosophy behind the proposed methodology, followed by the description of the three games in Section 3. Section 4 provides the feedback and precautions one should take while designing a game for a new course. Finally, the conclusions are given in Section 5.

2. Philosophy

One of the several reasons that motivated the author significantly to conceive the proposed new teaching methodology is to make the learning process for the students more interesting. The credit for stimulating such thought is due to the existing course evaluation system of IIT Delhi. At IIT Delhi, the students of every course are required to give two feedbacks during the semester of 14 weeks. It is, however, the teachers who are responsible to provide the students with the feedback forms designed by the institute. One is taken somewhere during the middle of the semester and the other one is at the end of the semester. The mid-semester feedback is very useful, particularly, from the point of view that the teachers can take corrective measures based on the students' feedback. A typical mid-semester feedback form contains questions like

- What in the course so far is new knowledge for you?
- Based on the course plan given by the Instructor, would you like certain topics to be added, deleted and/or emphasized?
- Any suggestions for improving this course in future classes in terms of teaching, examinations and interactions with students?, etc.

The author in his early years of teaching career has found about 50-60% of the students in a typical class of 60-70 students have responded that the course is not interesting. A close look into the responses revealed that these students are mostly those whose attendances were poor and spent relatively less time after their class hours (these information are also asked in the feedback forms) than their counterparts. These students also failed to provide constructive suggestions, which was not really expected from the age group of about 20 years old. When such feedback results were shared with other colleagues, mixed reactions were obtained. Some expressed that the students do not take the feedback seriously. Others said that it is normal because those who attended the classes regularly and studied seriously commented the course as interesting. The author, however, wanted to increase the "interesting" comment to at least 90% or more in order to establish the fact that a teacher must be in a position to motivate the students to learn, be they initially sincere or not. Hence, serious thoughts have began, which have culminated to the proposed methodology. Some of the fundamental thoughts were,

- What are the things a human being likes to do most?
- What a student enjoys doing at this age?
- What I enjoyed doing at their age?
- What makes people laugh?, etc.

Few answers to the above sole searching questions were: Playing or watching games and movies, and entertainment through acting, traveling, etc. Other psychological and teaching aspects (CET, 1999) were also taken into account. Assessing the existing constraints, the first one adopted was to simulate a travel situation. In this mode, the students were taken to places inside the campus, be it a workshops, laboratories, students' hostel, lift house, new machine/systems developed by the IIT Delhi's faculty/students and nearby shops, etc., where the relevant technical knowledge being used. For example, the students in their Machine Design course were taken to the carpet processing machines developed at IIT Delhi (Saha, et al. 2003a&b). In another instant, the students were taken to the 8th floor of the institute's main building to show the motors of lifts (elevators) with their ropes, winches, and electronic controllers. Once the students were also taken to a shop inside the campus where a flourmill to grind wheat was housed. In this visit, the students were shown all the machine components and they were asked to sketch the mechanism and the elements. The exercise was also to provide an improved version of the mill. These visits have generated sufficient interests amongst the students. Such outings also provided an opportunity to the students to have a break from the conventional classroom teaching within four walls. As a result, the feedback has improved substantially, particularly, from those who had relatively poor attendance and spent less time studying outside the class hours. However, there were difficulties related to the arrangements with the site people during the class hours. A lot of coordination was required because only smaller groups of 10-20 could be taken at a time to expose them to the systems. Hence, at least 3-4 visits during a week were required for the class of 60-70 students. Furthermore, for the courses that are more theoretical in nature, for example, Thermodynamics, etc., such explicit live examples are not easily available to demonstrate. So, alternate methods of interesting learning were needed. This has led to the three different games taken from the entertainment domain. Three games are chosen based their feasibility of implementation in a classroom teaching. They are:

1. Word Antakshari;
2. Dumb Charades; and
3. Jigsaw Puzzle.

All of the above have evolved from the fact that the young generation is very much fond of them. The first one is taken from a popular Indian game called "Antakshari" played in parties, be it a birthday, marriage, or to celebrate an achievement, etc. The second idea, "Dumb Charades," is taken from the school/college festivals, and inter-college competitions. The third one, "Jigsaw Puzzle," is taken from watching the kids and school children doing jigsaw puzzle with keen interest. Such puzzle was also used once as an entertainment activity in one of the 1999 Christmas Parties at the University of Stuttgart, Germany, where the author was present. Concepts similar to those conceived here are also used in the kindergarten schools in India and abroad. In this paper, the concepts are extended to technical education.

3. Proposed Teaching Methodology

In order to overcome the monotony of the traditional classroom teachings in the colleges/institutes/universities, and the one-way communication, a teaching methodology based on three fun games are proposed. In the present day teaching of technical education, fun is often disassociated from the classroom teaching, as if they are exclusively different. However, the students, like any human being, are very enthusiastic about the games like Antakshari, Dumb Charades, Jigsaw Puzzles, etc., that are played in family/student get-togethers, high-school/college festivals, and other places. These games, as used by the author in various courses offered in the Department of Mechanical Engineering of IIT Delhi during 2000-2005, are explained next.

3.1 Game "Word Antakshari"

The name has been derived from an existing Indian popular game called "Antakhsari." It consists of two words, namely, "Anta" meaning "End" and "Akshar" meaning "Alphabet." Hence, the complete word "Antakhshari" means "That starts with the end of something." In this Indian game, songs are sung. It is played between more than one team consisting of one or several members in each team. The rules of the game are outlined as

- The moderator of the game first sings a few lines of a song;
- When the moderator stops, a team, say, Team-1, should sing another song beginning with the last alphabet of the word uttered by the moderator. Team-1 gets about 30 seconds to think a song;
- If Team-1 successfully sings, it gets some points, say, 2. Otherwise, the next team, say, Team-2, gets the opportunity to sing;
- Once Team-2 is successful, it gets the bonus point, say, 1, and Team-1 gets zero point;
- Now, it is the turn of Team-2 to sing a song that is different than the previous two, and starts with the last alphabet of the preceding song.

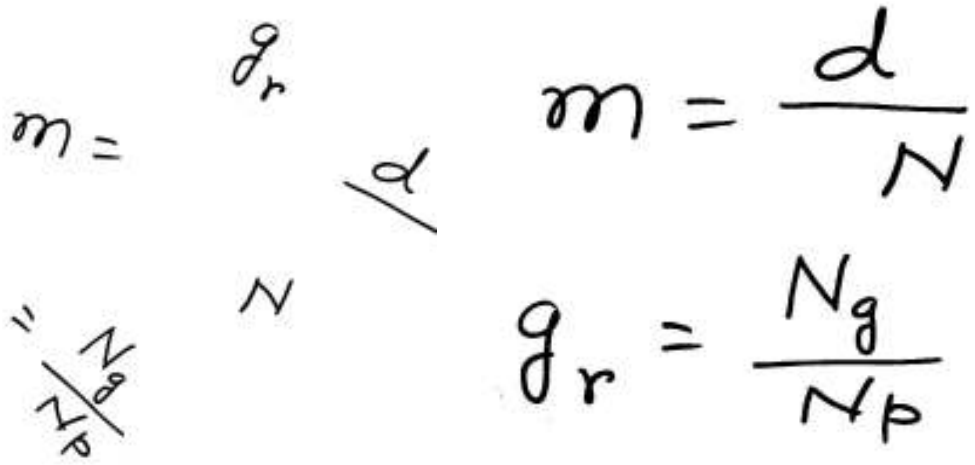
The game continues for several rounds depending on the time available.

Adoption of the Antakshari in its original form was difficult in the classroom, as all students were not able to sing. Besides, the songs using technical words are not known to exist. Hence, the name of the game is modified to "Word Antakshari," to emphasize on words than songs. For example, in the Design course, the author as a moderator says the word "Design." Then Team-1 has to say a word/phrase that starts with "n" but related to the course of Design. It gets about 20 seconds to recall the word. If Team-1 says "number of cycles," it gets 2 points. Otherwise, the chance goes to Team-2 for the bonus point. All other rules remain same as in the original Antakhsari game. In another course, say, in Kinematics and Dynamics of Machines, one could start with the word "Kinematics" and the Team-1 may say "Slider-crank mechanism," and the Team-2 "Motion generation," etc. Like Antakhshari, no two words will be repeated during the rounds of the game. The teaching component here is that the students have to be well conversant with the subject if they have to quickly tell the words.

3.2 Dumb Charades

Many of the readers of this paper may be already aware of this popular game. It is played between different teams. The rules of the game are explained below:

- One of the two members in a team, say, Team-1, like a dumb person, acts without speaking to express a word or a phrase written on the chit taken from the moderator. About 30 seconds are givein to think, and another 30-45 seconds to act;
- If the other member of Team-1 guesses the word/phrase correctly, they get 2 points. Otherwise, the chance goes to Team-2 for the bonus;
- In order to minimize the disturbances during the sit changing, Team-2 is asked to guess based on the acting of Team-1.



(a) Five cut transparency pieces (b) Arranged transparency pieces

m: Module of a gear; g_r: Gear ratio in a gear pair; d: Pitch circle diameter of a gear;
N: Number of teeth in a gear; N_g and N_p: Numbers of teeth in a gear and a pinion, respectively.

Fig. 1. A jigsaw puzzle in Design course

Here also the author has acted as moderator. He had several words like "Factor of Safety," "Von-Mises Stress," "Fatigue failure," etc. from the Design course, and "Degree of freedom," "Frequency," etc. from the Mechanical Vibration course written on the chits. Students were asked to pick up one from several chits kept in an envelope. This game is one of the most entertaining where almost every student including the teacher laugh together, which has an indirect effect of bringing the students and teachers together for closer and healthier interactions. The game appears to be the most difficult one, as the students have to be very creative in finding out ways to act. On the other hand, the other team partner has to be quite familiar with the terminologies taught in that subject.

3.3 Jigsaw Puzzles

The jigsaw puzzles are very popular amongst the kids. This is a game where several pieces of a picture of an animal, historical place, famous people, etc., are to be assembled. The one who does it fastest wins. It is also a very good educational tool where the kids and children learn geography, animal shapes, atlas, etc. The same concept is extrapolated in technical education. Here, several equations are written and the diagrams are drawn on a transparency sheet, which are cut into pieces, as shown in Fig. 1(a), and put inside an envelope. The rules of the game are as follows:

- A team, say, Team-1, picks up one envelope;
- In about 45 seconds, Team-1 must assemble the pieces on the glass of the OHP, Fig. 1(b), to get 2 points;
- If Team-1 fails, the job can go to Team-2 for the bonus. However, if the teacher wants to avoid the sit changing time, the answer could be told;
- Team-2 is now given a new puzzle.

Note that if the classrooms are not equipped with OHPs, the equations and diagrams can be written/drawn big on plane sheets, which then can be pinned on a big cardboard placed against the blackboard. This game is also fairly difficult, as the students now have to remember the equations and diagrams in order to successfully complete it within the time limit.

3.4 Mode of Operation

In this section, the mode of operation to play the above games is presented. At present, these games are played in one of the tutorial or practical classes. So far the games were played in four courses taught by the author in the Department of Mechanical Engineering, IIT Delhi. The class strength in these tutorial/practical classes was between 15-35. The courses are:

1. Mechanical Engineering Design: A core course offered to the 3rd year undergraduate (UG) students. Played three times since 2000;
2. Mechanical Vibration: An elective course for the 3rd and 4th year UG students.
3. Kinematics and Dynamics of Machines: A core course for the 2nd year UG students. Played twice since 2004;
4. Design of Mechanisms and Manipulators: A core course for the postgraduate (PG) students specializing in "Design of Mechanical Equipment." Played once in 2005.

Since the proposed methodology is still in the experimental phase, it is played only once during the semester. It is played somewhere during the middle of the semester to give the students break from their regular activities of either solving problems in the classroom or carrying out experiments in the laboratory. For a typical class of 20 the games were played in the following manner:

- Teams of 2 students are first made. Hence, ten teams are formed. They are told about the rules of the games, as explained in Sub-sections 3.1-3.3;
- Word Antakshari is played first. Time limit of 15 seconds are given. For the bonus points also the same time is given. In an average, one round of game takes 7-12 minutes;
- Dumb Charades is played next. About 30 seconds are allowed to think and additional 45 seconds are given to act. This takes about 20-25 minutes for one round;
- Jigsaw Puzzles are played last, where each team is provided about 45 seconds. Here, both the team members come to the OHP to assemble the equations/drawing pieces. This takes about 20-25 minutes.

Thus, a class of one-hour can be comfortably used to play the games. The total points scored by the teams are then declared. The teacher himself or herself can keep track of the time limits and writes the scores on the blackboard. The winning team was given either a chocolate or a "Big Thank You." So far, the points were used to decide the winning team only. However, one may like to convert them into marks as well. The author does not support this conversion, as the fun component may disappear. On the contrary, it is suggested that these points can be kept in mind while awarding the final grade. Regarding the time spent in creating the games, the first two games did not take much time. The third one took some time to create. Typically for about 15 puzzles it took 5-7 hours. The author is planning to create more such games.

4. Feedback and Precautions

As per the feedbacks from the students of all the four courses, the games were new to them and the enjoyed very much. In fact, quite often the students wanted to repeat such games during the semester. It is pointed out here that the games in Mechanical Vibration were played with the request from the students who came to know about them played in the Design course. Moreover, when such games were played in the presence of two other teachers who shared the courses with the author also appreciated the effort, and the effectiveness of the approach. Since such teaching methodology has not yet formalized at IIT Delhi, it was restricted to only one class during the semester. More such practices and experiences by other faculty in IIT Delhi and other institutes will help to formalize the methodology.

Some precautions are highlighted here for any teacher who wants to experiment with the proposed methodology. They are:

1. Since the games are played in a point rewarding basis, the students immediately switch to competitive modes, and try to find ways to score even if they are not truly right. For example, in a class of Mechanism they may say the word "Stress" in the Word Antakshari. If they are not awarded any point based on the fact that the word does not belong to the subject of Mechanism, the students start arguing. Hence, appropriate stand must be taken by the teacher for smooth running of the class;
2. Regarding the dumb charades, relatively shy students hesitate to act. Also, it is important that the partner starts saying words for the possible guess which the actor can indicate yes or no. Without such prompts the game may become dull, and the other students of the class may can start talking, hereby, causing disturbance in the class;
3. The designing of the jigsaw puzzles require the following care:
    a. The cut pieces put in an envelope should have the counting of the pieces written on the envelope so that any lost piece can be easily detected;
    b. Solution sheets should be prepared which must contain the counting of the pieces so that they are shown easily by the teacher;
    c. It has been observed that more than 4-5 pieces it is very difficult to assemble in 45 seconds;
    d. Since the transparency sheets are very thin, they are prone to slide away on the glass of the OHP. Hence, it is advised to have bigger pieces cut. Alternatively, a thicker material like polypropylene sheets can be used.

The above precautions are likely to be taken into account by the author in his future classes.

5. Conclusions

This paper presents a methodology of teaching beyond the conventional classroom lectures, namely, the site visits and the fun games. While the site visits have some limitations, as pointed out in Section 2, the three games proposed in Section 3 are very effective for teaching and learning of technical subjects. The games have been played since 2000 in four different courses taught by the author in the Department of Mechanical Engineering of IIT Delhi. Since 2003, the feedbacks of the courses are very good. In fact, in the mid-semester feedback of an UG course offered during Jan.-May, 2005, 83 out of 85 respondents considered the course as very interesting, whereas in a PG course offered during the same period, all out of 14 respondents considered the course as enjoyable. The sharp improvements are mainly due to the changes in the teaching style based on the philosophy mentioned in Section 2 and the introduction of the games. Through this paper, the author wishes to share his experiences of the proposed methodology with other teachers and educators. Any comments on these teaching experiments are welcome. Additionally, if anybody needs any help to create such games the author can be contacted.

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