Product Dissection: A method for Hands on Engineering Education

Aditya Bhatnagar, Director

Drona Edutronics Ltd, Chandigarh, India 160101,

aditya.bhatnagar@e-drona.com

***Abstract*—There is a need to make Engineering education more hands on. Traditionally this was done through labs. However, a method developed for hands on engineering, understanding engineering concepts, choices and designs is Product Dissection. The history of PD is examined and its' evolution as well as the superset of PD – Experiential Learning which has also developed from the time of Confucius to Kolb. The design of a PD course is seen as done at Stanford and other North American Universities, and is adapted to an Indian University in its' inaugural year. The course design, its' comparison with existing models and relation to EL are shown. The practice of the course, challenges faced and what were the results of the evaluations done are given.. Also the type of assessment needed to drive engagement and hands on work by students is illustrated. In conclusion the problems faced are summarized and their resolution discussed**

Keywords—Product Dissection (PD), Experiential Learning (EL) Course Design, Hands-on, challenges

I. INTRODUCTION

There are several schools of thought on how to make Engineering education Hands-on. One of the obvious analogies is that to medical education wherein cadavers are used to get a hands-on experience of surgery and anatomy. Going forward in this analogue, the concept of product dissection was introduced by Sheri Sheppard at Stanford around 25 years ago [1]. The course ME99 introduced by Sheppard became popular and was adopted in many other universities and was also widely discussed at the ASEE meetings and symposiums. Reference has been made to one such symposium [2] where the dissection of some products is exemplified and Dissection 2 X 2 matrix discussed.

In India this is specially, relevant from the industry point of view. Industry feedback suggests the lack of practical skills, unfamiliarity with tools etc. The Indian engineering pass-out is considered to be more a theoretician than a practitioner with few hands-on skills. Encouragingly, a similar concept was introduced by Sam Pitroda called Tod Phod Jod at the school level [3].

There is more to dissection than a mere tearing apart and putting together. Importance needs to be given to understanding how theoretical concepts learnt are being applied, what are the consequences of the imperfect world, why is a product designed as it is. The experience in these desired outcomes has been a mixed bag, even at the US institutions where it was practiced. Several studies are available on dissection as well as experiential learning [4]

In this paper the product dissection as done in Year 1 of the engineering course at a new University in Uttar Pradesh is examined along with the experience of students, faculty and staff. The lab set up and methodologies are also mentioned. It is hoped that this experience will help in developing this technique further in Indian engineering colleges.

II. BACKGROUND AND CONSIDERATIONS

A. History

The idea of experiential learning is very old. Confucius' famous saying of "You tell – I forget ..." to the idea of learning through apprenticeships and our very own Gurukuls where practice was emphasized over theory. The rote learning was essential due to the paucity of or cost of written materials. Today, with Googling being a way to find out what, why and how the relevance of experiential learning remains. In the practice and teaching of engineering and medicine this is indeed a valuable part of the pedagogy. In medicine dissection is practiced widely but not so in engineering understandably because and engineer is unlikely to encounter varieties of the same machine but will need to deal with several types of machines and processes.

The idea of product dissection was developed as a course initially for mechanical engineering freshmen and sophomores by Sheri Sheppard at Stanford and called the ME99 course. This evolved over the years with several flavors and with inclusion of design, graphics etc. A brief background is given below.

The aim of education is to get understanding and to reach the higher levels of learning as in Bloom's Taxonomy. A nice summary definition is provided in [5]

"Understanding is not something that comes free with data banks and thorough practice; it is something won by the struggles of the organism to learn- to conjecture, probe, and puzzle out forecast and so on. Likewise ready recall of information and smooth execution of procedures do not guarantee active use of knowledge and skills as the learner later in life strives to cope creatively with new situations. On the contrary, there is considerable risk that a drill and practice regimen may yield knowledge and skills more contextually welded to very particular circumstances, less labile, less easily transferred. In Summary, understanding and active use become central goals of instruction to be pursued with particular care rather than taken for granted."

Product Dissection is still relevant more so in India as our engineers are perceived to be not hands on. The wider idea of experiential learning and hands on learning as a subset is very relevant today. Undoubtedly computer simulations do help in learning and understanding but can hardly replace the learning in a real context. Besides and engineer will be expected to solve problems in real life and not on animations on a computer!

B. A model of Experiential Learning

A model of the mechanism is given in [4]

"EL is a sense making process of learning that actively and reflectively engages the inner world of the learner as a whole person (physical-bodily, intellectually, emotionally and spiritually) with the intricate 'outer world' of the learning environment (nature, place, social, political)."

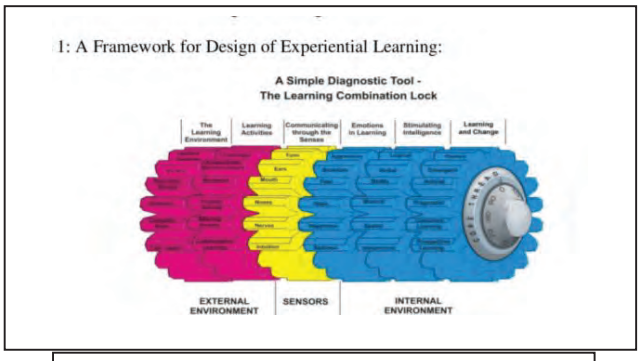


Fig 1

The above two figures illustrate the thinking that goes into designing an experiential learning experience

C. Product Dissection models and practices

Product dissection course practitioners have documented their experiences and have also also dun studies some of which involved video recording of the students as they proceeded to dissect and explore a product. Some examples are given below

Reference [5]

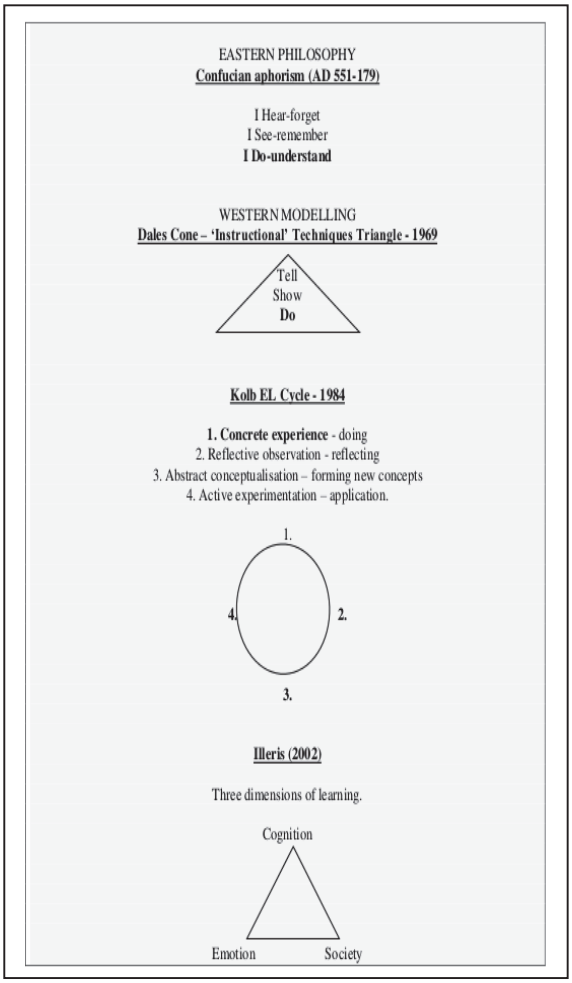


Fig 2

In this study the following are notable conclusions

- **Assessment drives learning**
- **Developing students' abilities to question, observe, and actively use and link theoretical knowledge to hardware experience should be a central goal of education to be pursued with particular care rather than taken for granted**

- **Developing an active learning community and supportive classroom culture**

Requires new roles for teachers and students: Based on our research, we designed a class called "Exploring Engineering Intuition" to explore how to help ourselves and our students

(a) become better observers of the world around us; (b) challenge assumptions through what-if questions about hardware; (c) motivate interest in learning theoretical concepts by relating them to hardware. In another study called the Cornerstone Project for Fresh men in line with a Capstone project for seniors reference [6]

"In many engineering students' educational career these are the most interesting and rewarding courses because they offer the student the ability to apply the culmination of their education to an engineering design problem. This is often described favorably by the student as their first "engineering" experience and in general it provides a greater appreciation for the field of engineering and a motivation for greater knowledge. If this type of experience could be offered to first year students it would significantly enhance their engineering education. However, the challenge for a first year engineering program is balancing the required background knowledge for design against a procedure for demonstration; this is an even greater challenge for a common curriculum.

The objective of the Cornerstone is to instill in first year engineers enjoyment from learning, motivation to continue learning, and genuine intellectual curiosity about the engineering in the world around them"

A framework for the dissection activities was developed by Prof Sheppard and shown here from reference [2]

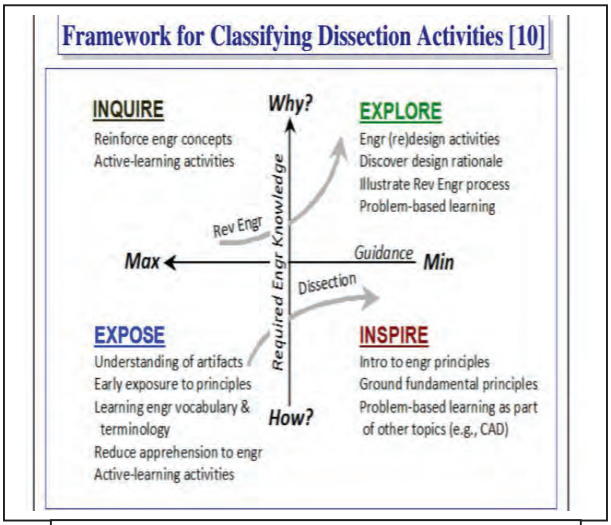


Fig 3

In the above Expose and Inspire are suitable for year 1 and 2 and inquire and explore for year 3 and 4

A word on how the ME99 course was structured and also its objectives taken from Reference [7]

"Course objectives: The objectives of this course are to give mechanical engineering students:

(1) A number of experiences in disassembling and reassembling mechanical systems/artifact sin order to be able to reason about function

(2) Insight into the importance of functional specifications in design and how they map into specific functions

(3) Awareness of the non-unique mapping between functional specifications and the final objectives design solution (i.e., multiple solutions)

(4) The ability to communicate (orally, graphically, and textually) about the function of mechanical components.

(5) Appreciation of technological history.

Targeted Student Group: This course is targeted at freshman- or sophomore-level engineering students. It is particularly well-suited to students who have had little "hands on" experience. It is assumed that students taking this course have had exposure to basic physics, but no prior exposure to engineering graphics, statics, strength of materials, or sketching.

Approach: ME99 is based on a series of in-depth dissections. "Dissection" in this context refers to a process of studying the intent and function of a mechanical system, disassembling it in order to see how this intent is realized, then reassembling it. The dissections are of a fishing reel, a ten-speed bicycle, a multi-action toy, an electric drill, and an individual project (o be selected by each student). These dissections are supported by lectures, class activities, tours, and assignments.

Unless specified, dissections are done in team of two.

Timing: This course is being offered for three credits

There is also a wealth of literature available on the effects of product dissection and how it may also actually lead to incorrect learning. A study worth looking at is the Private Universe which deals with diverse science and technology learning experiments which showed how intuition can be wrong and how despite theoretical learning, the student would first use intuition. As the saying goes – When everything else fails read the manual. This can be seen in reference [8] where the important role of TA's or in the Indian context lab assistant is also discussed

III. ADAPTATION TO INDIAN CONTEXT

The above information and literature forms the background for the design and implementation of a Product Dissection based course which was called ' How Things work' at a new University in the hinterland of Uttar Pradesh, India.

A. The Backdrop : Looking for more than 3 Idiots

Engineering educators in India, particularly those in Tier 2 and Tier 3 institutions, are faced with several challenges, some of

which are enumerated below which impact the design of the course and the selection of the pedagogy.

1. Apart from language, the ability to comprehend and communicate with clarity
2. The motivation to enroll for an engineering program- ranging from being forced to by their family to bettering their marriage prospects thus leading to skewed expectations and attitudes
3. The perception that having 'got into' a college of engineering a job and a future and heaven are assured
4. Having struggled and slogged to get a rank in engineering entrance and having been told that the last two years of school is the last time they have to slog, the student comes with an attitude of getting a lot of free time and easy assignments
5. The small percentage of those who are genuine engineering career seekers face the prospect of a lot of theory, few application in labs and fewer links to real life.
6. The experiments and labs are structured to demonstrate and verify laws and principles which are not appealing to the students and do not challenge them
7. Equally students by and large do not like to be or wish to be challenged. It is surprising that students even in Year 1 and 2 will claim that they have no time for extra projects perceived to be inessential
8. The Indian student is not exposed to tools though increasingly some students so come with some background in programming or more accurately coding
9. The Lab Technicians and faculty are also not hands on and need a lot of training as well as motivation to run a course like this

B. How "How Things Work " was Restructured

The course objectives were restructured to adapt to some of the above constraints. Additionally two types of gadgets were taken up for dissection: one not requiring tools and one needing tools. Each student group was expected to dissect at least 2 gadgets during the semester. Earlier ¾ were planned but the being the first semester of the inaugural year, the labs could started up late in the semester.

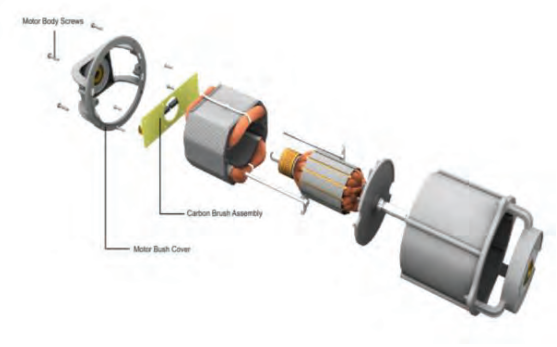
The Objective: To expose students to engineered gadgets and equipment around them in order to foster a spirit of inquiry, handling of tools, and understanding engineering processes and science principles

Broad Course contents: The course has a series of lectures on how things work, engineering principles and the physics and chemistry underlying in gadgets and devices used in everyday life. . The course will require intensive study fostered in the Tutorial and practical work in the lab where the student group will be assigned gadgets/ exercises. Each exercise will consist of product dissection, documenting how it works, principles being used, materials used and then reassembling & get it to work. The exercises will demonstrate challenges of a design nature where changes in the gadget are done, and the student is expected to predict what should happen

The course structure was 1 lecture, 2 hour Tuts and 2 hour Lab per week. We would have liked to have had a 4 hour lab per week but this could not be done due to paucity of time and resources

The gadgets chosen were: Mixer, Ordinary bicycle, Door closer, electric hand Drill and Flush system

For the Mixer an interactive 3D Flash simulation was also set up to enable better understanding. A snap shot is given below



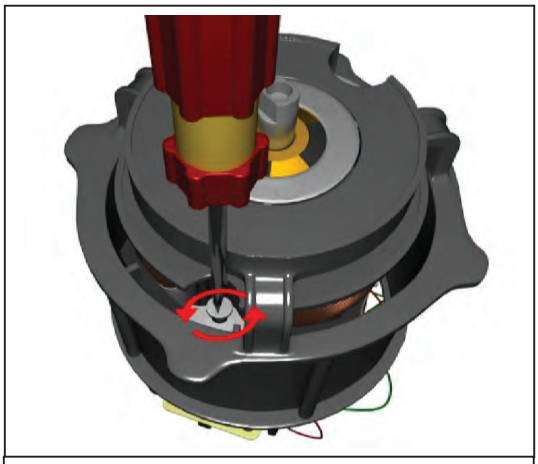


Fig 4

In addition training on tools was given to those working on door closer and bicycle. (The cycle has some special tools designed for opening the pedal assembly for example.)

C. Some Challenges While starting

The major challenge was acceptability and that such a thing is not done in any university. Also, that such courses are more relevant at IITs//NITs. The faculty were made to understand why a hands on course is much more essential for students in a Tier 2/3 setting because

- Socially they need more motivation and guidance to stay on course

- Comprehension issues can be addressed here when they relate what they do to the written word
- Concepts make more immediate sense and help them to engage in other classes as well
- Many have a knack or they might have actually worked on their own cycles etc which gives them some confidence in a strange world of gradients and curls
- The Lab Technologists had to be restrained from showing off their knowledge or making intuitive guesses and robbing the students a chance to explore

Admittedly these were only partially overcome.

D. Mapping to Experiential Learning & Product Dissection

The practice that we carried out over one semester was planned keeping the above in mind and were mapped as follows

Area	EL	PD	HTW
Objectives	Engaging inner world and outer world	Functional reasoning, Functional specs, non-unique mapping, present and history	Exposure, Tools, Functional reasoning, Connect to theory, learning with hands and making report
Types of artifacts	Could be any including simulations	Gadgets like multi speed cycles,	Simpler gadgets and use of simulations
Running of course	Based on Kolbs EL cycle	In depth dissection moving from expose to inspire	Dissection in simple terms with what if speculations and learning of function
Team size	-	2	4

EL – Experiential Learning, PD – Product Dissection, HTW – How Things Work

IV. Execution and Findings

The course was executed in a large lab space with gadgets being provided to groups of 4 students along with suitable tools. Training was taken from local bicycle repair shops on the cycle dissection and was done by lab technicians first along with interested faculty. Motivating faculty was difficult though the lab technicians and students loved this course and the labs

However, the students were content to tear apart and put the gadgets together somehow rather than follow any scientific method. Also they were not too concerned about the function or why each component was there, the choice of its' material etc. The faculty and lab techs who needed to raise leading questions and use assessment/ viva as a tool for a deeper exploration did not happen as the faculty and lab techs themselves were discovering.

As a corrective measure a paper based on the dissection with leading questions was designed. Some examples of the questions is given below

The question paper was given in advance with students allowed to consult as well as Google for 4 days and then write the answers in a classroom

- What is the difference between the dry grinding blade and the wet grinding blade? What will happen if
  The dry grinding blade is used to make a paste? Explain the shape and the reasons for keeping the shape of
  the blades as they are
- How will you fix a door closer such that the door is kept open all the time and needs to be pushed to
  Close it. You can explain with a line diagram or a sketch
- In a cycle how does idling take place? Idling is when the cyclist does not pedal but the wheels are still
  Rotating. Does the pedal mechanism have a clutch?

The results of marks distribution out of 5 are given below reflecting that such understanding as expected in the questions above did not take place

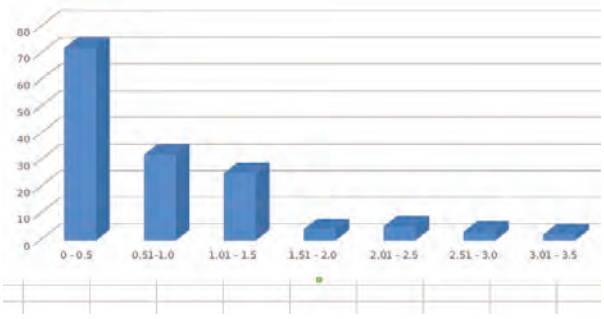


Fig 5

After the semester, the lab techs were asked to make models which demonstrate the 15 different questions which had been designed to encourage discovery and investigation. Some of these were made and shown to students after the winter break.

V. Conclusions

Based on the above experience following are the conclusions

- A Product Dissection course is very much needed. And that this should start from year 1 to give students a sense of what engineering is all about.

- The course would also promote a hands on approach and an abiding interest in engineering. Note how young persons are attracted to robotics as it is a lot of doing
- The course needs to have the faculty and Lab Techs well trained on all the aspects. The data and background was sent to the faculty but a lot more on motivation is needed
- The barrier of not been done before is more in the minds of techs and faculty rather than students
- The mentoring and guiding during and after dissection need a lot of training including mock classes and mock dissections done with faculty
- This ought to be started at an institute which is reasonably mature. Our starting at a new institute doing its' inaugural semester led to lot of problems
- The assessment of the nature which is shown above needs to be done throughout the dissection period rather than at the end
- Faculty need to be very hands on and creative for this course. The faculty we had were all M techs from the IITs, but this is going beyond academics
- The mapping of course characteristics needs to be done keeping the student population in mind
- The course be scheduled in Semester 1,2, 3 and 5 progressively growing towards design and product realization

ACKNOWLEDGMENT

I gratefully acknowledge the opportunity given by Mr Mohd Wajid, Pro Chancellor Glocal University UP for a chance to launch this course in the inaugural year.

I am very grateful to Prof Sunil Kale HOD Deptt of Mech Engg IIT Delhi, for his guidance support and structuring of an idea into an academic course

I am also very grateful to Prof Debabrata Goswami Deptt of Chemistry IIT Kanpur for his guidance and interventions even at the implementation stage

REFERENCES

All the references are taken form the Internet and are freely available for reference

[1] Sheppard, S.: Mechanical Dissection: An Experience in How Things Work, Proceedings of the Engineering : : Curriculum Innovation & Integration, Santa Barbara, CA, Jan. 6-10, (1992)

[2] 2008 ASEE Annual Conference & Exposition : A Hands-On Product Dissection Workshop for Engineering Educators *http://gicl.cs.drexel.edu/images/3/39/ASEE.Workshop.Slides.pdf*

[3] Anubhuti Bishnoi Indian Express 11th Oct 2012 NIC lesson on learning: Tod-Fod-Jod *http://indianexpress.com/article/news-archive/web/nic-lesson-on-learning-todfodjod/*

[4] Colin Beard Sheffield Hallam University (doctoral Thesis): Experiential learning: The Development of a Pedagogic Framework for Effective Practice. *http://colinbeard.co.uk/academia/publications/files/*

[5] Margot Brereton, Sheri Sheppard and Larry Leifer ;International conference on Engineering Design ICED 95 Praha, August 22-24, 1995: How students connect engineering fundamentals to hardware design: Observations and Implications for the Design of Curriculum and Assessment Methods *http://www-adl.stanford.edu/images/fundhdwr.pdf*

[6] Thomas Doyle, McMaster University *:* AC 2009-2068: cornerstone design: Product dissection in a common first-year engineering design and graphics course *http://scholar.google.ca/citations?view_op=view_citation&hl=en&user=tkWC_bUAAAAJ&citation_for_view=tkWC_bUAAAAJ:hC7cP41nSMkC*

[7] Prof. Sheri D. Sheppard ME99 - Mechanical Dissection Autumn, 1992-93 ME99 Course Outline *http://www-adl.stanford.edu/images/me99sylb.pdf*

[8] Jeremy Roschelle, Reed Stevens & Charlotte Linde Institute for Research on Learning Drill Dissection Formative In-Depth Assessment Report *http://www-adl.stanford.edu/images/drillass.pdf*