Chapter 19
Improving Classroom Delivery of Engineering Education Through Design Thinking

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Abstract Teaching is an art which requires systematic exploration in manifestations, be it curriculum design, pedagogical strategies and theories, teaching material and practices, and technological interventions. Due to the interface of technology and the mitigating attention span of the students, teachers have realized that the old method of teaching is not relevant anymore. As a result in the different courses offered at the Engineering institute, the teachers are adopting divergent thinking, synectics and design thinking for better understanding of the concepts. Design thinking offers better solutions to the problems and includes analogies and synectics to clarify the concepts. Design thinking aids better student participation and fosters teacher-student relationship. The students are encouraged for team based learning, which make them more attentive. This paper discusses how design thinking has been applied in two popular courses at Birla Institute of Technology and Sciences, BITS Pilani namely General Biology and Computational Fluid Dynamics. The feedback suggests that through analogies and design thinking the profound concepts are made easy to grasp.

Keywords Engineering education · Design thinking · Innovative pedagogy

19.1 Introduction

Teaching can be considered a science as well as an art which requires systematic research, exploration and innovation along with constant development and adaptation in methods and practices. Even with a static curriculum, the strategies of teaching can be labile with the purpose of constantly engaging (Coe et al. 2014). To be effective,

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instructors may even integrate multiple strategies over a single course. Knowledge and skills transfer is closely linked with high classroom engagement (Thompson and Irvine 2011). This is as true for engineering courses as it is for any other course.

Even a cursory literature survey shows that research on teaching enhancement in engineering courses have largely revolved around vertical thinking ideas (Vidal 2003). De Bono (1970), who is known as the lateral thinking pioneer of the century, states that “the emphasis has traditionally always been on vertical thinking which is effective but incomplete”. He further emphasizes that although analytical thinking is excellent, there is still value addition possible by creative or lateral thinking, which is generative rather than selective in process, and where labels are less water tight than in vertical thinking (De Bono 1970). Educators are constantly grappling with the thought of engaging students fruitfully in learning in the classroom. Design thinking can be employed to solve complex problems faced in all walks of life and different business sectors including education. Herbert (1996) propounded that greater emphasis on cognitive psychology and science of design could help solve complex societal problems.

Design thinking explores new ways to transform the approach to solve such complex problems. It focuses on the needs of the beneficiary, identifies the existing problem in totality and redesigns the models, processes or practices to arrive at a solution. It is fundamentally a user focused process of solving problems innovatively. This process comprises of various elements like observation, collaboration, exploration of latest needs, re-defining of problem statements, visualisation of ideas and concepts, prototyping and organisational change. This work demonstrated the practice of design thinking in the pedagogy of two courses offered at Birla Institute of technology and Science, Pilani. The examples are illustrated from General Biology, a course offered to first year students and Computational Fluid Dynamics, which is offered as an elective course to engineering students.

19.2 Role of Design Thinking

When the students are banking on rote learning, in aspiration to get grades, design thinking carries a lot of importance. It is not only relevant for Science, Technology, Engineering and Maths (STEM) courses but also for humanities as it enables students to think critically and go beyond just asking questions. A few examples could be explanation through synectics, metaphors, divergent thinking and lateral thinking. Edward de Bono had underscored the importance of lateral thinking and interlacing it with humour can lead students think different from familiar patterns to create new patterns. Design thinking has a few well defined elements which have both convergence and divergence in all phases that differentiate between a problem and a solution stage.

Thoring and Muller (2011) defined design thinking process in different stages like understand, observe, define, ideate, select ideas, prototype, test and iterate. Runco and Acar (2012) showed that divergent thinking in the design thinking leads to increased creativity. Divergence in design thinking merely does not emphasize the newly generated idea but also reforming the existing information and knowledge related to the problem (Brown 2009). Divergence relates to the ability to identify multiple solution options to a problem and this then leads to a changed point of view. Convergence utilizes various elements and outcomes of divergent thinking by bringing them together meaningfully through use of methods, patterns, concepts and frame works (Linderberg et al. 2010).

19.3 Design Thinking Application

There are numerous methods used in design thinking. Some of the common characteristics of these methods are: human centricity, collaboration and teamwork, interdisciplinary teamwork, ideation and experimentation (Thoring and Muller 2011). Irrespective of the method used by individual design thinker in solving a problem of any nature, these characteristics are used in one or the other form (Brown 2009). Similarly, design thinkers use different approaches and processes; however, they too manifest certain common attributes while solving problems. They are empathetic, observant and curious, knowledgeable, holistic and integrative thinking, tolerant (deferring judgement), prognostic, experimentalistic and optimistic. The integration of design thinking in the courses emphasizes on team based learning and exchange of ideas amongst students from different engineering field. Unlike traditional method where teacher instructed and students listened, this method encourages people-oriented problem-solving method. Keeping in mind the positive implication of design thinking, where students are given enough liberty to participate in discussions, putting forth their ideas and encouraged for learning through analogies. By doing this the interaction between teacher and students increases and attention also bolsters because of the active participation of the students.

19.3.1 Design Thinking in Biology

Teaching Biology to Engineering students is a challenging task as these students have limited background knowledge of this subject. General Biology is a foundation course offered to all the students at Birla Institute of Technology and Science. Keeping in mind ‘creative play’, the following were incorporated into the teaching modules which followed standard textbook (Enger and Ross 2011). These examples show how a few basic concepts from a General Biology class made teaching and learning interesting by employing creative activities.

Example 1: The Concept of Neuron Functioning. The concept of neuron functioning is taught by taking example of how the neurons are fixed using the balance of $Na+$ ions inside and outside of the cells. $Na+$ concentration is maintained higher outside the cells to maintain resting potential. A group of select students are claimed to be lovely “Sodium Guys” who need to be out of the classroom (classroom represents a neuron) because in resting potential, Na+ ions are outside the cell. After asking the “Sodium Guys” to go out of the class, followed by closing of the door, the door is tapped (which represents physical or chemical signal to the neurons to excite it) and then one part of the door is opened (the door represents the Na+ gated channel) and a few Sodium guys are asked to come inside, once they are in the other part of the door is opened and other “Sodium guys” are asked to get inside. This represent that opening of some of the Na+ gated channels due to physical or chemical induction, allow some Sodium to come inside which in turn allow more Na+ to come inside and thus generating the action potential.

Example 2: The Human Digestive System. When teaching about the Human Digestive System, the reference to “secretion of saliva from salivary gland” is made. As saliva secretion takes place while eating food or just thinking/looking/smelling the food. To explain this, a few chocolate candies’ images and other “yummy food” images are shown. The chocolates are distributed to a few students and they are asked to eat. The students who did not take their breakfast were asked to raise their hands. They are then shown images of delicious food. Now they are asked (both who had chocolates and who did not have breakfast) if their mouth is watering. The concept of “Simple Reflex” and “Conditioned Reflex” mechanism of salivary secretion is told. In simple reflex, because the tongue pressure sensor sense the presence of food, it simply passes the signal to “salivary centre” in medulla asking it to send signal to salivary gland for saliva secretion which do not need the help of “Central Nervous System” (CNS). While in case of conditioned reflex (when one is not eating food still have mouth watering) is now visual/olfactory/hearing inputs (looking/smelling/listening about food been processed through CNS to ask salivary control centre in medulla to initiate saliva secretion from salivary glands.

Example 3: The Central Nervous System. To teach about the coordination of hand and leg movement to achieve quicker task, the nodal points present in muscles especially elbow and knee are referred that locally control hand and leg movement. To relate it to the students’ passion of cricket, it is asked which students play the game well. Once some students claim that they do, a chalk is thrown at one of them, who then catches the chalk with ease. It is explained on this account that the nodal points of this individual have been trained so well that they can regulate the movement of their hand without the direct involvement of CNS especially for quicker task like catching a ball.

Thus in all the above three concepts of teaching, it has been observed that the use of ‘creative activity’ increases involvement of the students and the concepts are learnt with ease.

19.3.2 Analogy in Computational Fluid Dynamics: Shock Capturing and Shock Fitting Approaches

As part of the application of design thinking, analogies or more broadly metaphoric activities can help students grasp complex ideas. This is because the analogy creates a mental foothold that can be extended and evolved. In the following example a topic from the course 'Computational Fluid Dynamics' (CFD), is elucidated using an analogy from basic mathematics. This helps define the main CFD idea of shock capturing and shock fitting (Anderson 2012), in a simpler, novel and more interesting manner, rather than directly stating textbook content.

For fast moving objects such as an aircrafts, the fluid flow around the object is affected by shock waves. For example, a bow shock occurs around a blunt nose when the free stream flow is supersonic, or faster than the speed of sound waves (Fig. 19.1). The resulting 'shock' is a front or surface which creates sudden or abrupt change in flow properties of the fluid. The generation of shock waves are due to the fact that fluid molecules ricochet off the moving surface, and stay ahead of the surface, thereby producing pressure or sound waves. When nose approaches sonic velocity there is a piling up or compression of theses sound waves in front of the nose creating the shock.

For aerospace technology, accurate simulation of the surrounding fluid flow containing the shock waves is clearly important. Shock capturing and shock fitting are two CFD approaches to this end. The difference between the two approaches is that in shock fitting, the property values before and after the shock need to be known (from exact relations) and so does the position of the shock. Then CFD only resolves the flow in the region between the shock and body. In shock capturing, CFD resolves

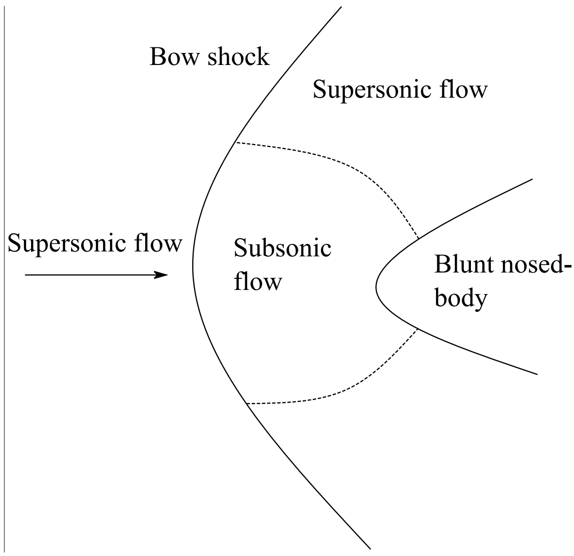

Fig. 19.1 Bow shock around a blunt nose in supersonic flow

the entire flow including the shock wave. To grasp the difference in the philosophy between these two approaches a mathematical analogy is proposed. To follow this analogy the student only needs to know high-school level mathematics. Consider a simple mathematical equation in x and y for which it is required to generate the x, y plot:

$$e^x = y * 0.1 \tag{19.1}$$

Consider the following two approaches to accomplish this:

Approach 1. Since the value of constant e is known (2.71828), then for x in any required range, say: 1, 2, 3 … n, the corresponding y is simply calculated as:

$$y = e^x / 0.1 \tag{19.2}$$

Approach 2. Equation 19.1 is converted (using logarithmic rules) into the form of a straight line like this:

$$\ln y = x - \ln 0.1 \tag{19.3}$$

So on a semi-log graph with ln y on y axis (x as usual on x axis), from the known y-intercept (−ln 0.1 or 2.3), and slope 1, a straight line is plotted. For any x the corresponding y can be extrapolated from the straight line.

Approach 1 is similar to the shock capturing approach in the sense that no other information or theory is required to generate a solution. If Eq. 19.1 is considered analogous to the CFD governing equations (GEs), the direct solution approach used to solve Eq. 19.1 is analogous to shock capturing. The extents of ordinate falls out directly as a result of the calculations, and it is not required a priory to plotting the (x, y) data. In the same way, there is no need to know beforehand the position of the shock wave when using shock capturing approach, because the shock wave is part of the generated solution.

Approach 2 is similar to the shock fitting approach. Here additional theory in the form of logarithmic rules and the form of the straight line are applied. This is analogous to 'extra information' required to calculate flow variables along the explicitly introduced shock wave around the body (Fig. 19.1). In the same way that unknown y values from Eq. 19.1 can be found using the straight line, the introduced shock wave also focuses the CFD solution on the area between body and shockwave. In the same way that slope and intercept are known before y data is generated from Eq. 19.1, the area where the governing equations are required to be resolved is known before the governing equations are actually applied.

19.4 Conclusions

Design thinking is both a tool and a strategic approach. As a tool it provides customer-centric solutions to the products or services through multi-disciplinary approach. Whereas, in strategic approach it helps overcome the magic view and fixed mind set to the problem solution approach and help bringing new energy and thinking to problem solution. It develops collaborative skills, an attitude of questioning, challenging and introspecting within the organisation and individuals gain greater confidence, sharpen their problem solving skills and questions status quo.

For successful integration of design thinking in teaching, it requires shift in thinking orientation in teaching fraternity and the stakeholders must recognize the need for investment in this process to assure long term and sustained success of the Academic Institutes. The examples narrated from two courses namely General Biology and Computational Fluid Dynamics imply that teachers do not leave any opportunity to explain the concepts in most creative way. By doing so, students find themselves responsible to learn and become more active as they are part of the concept as in the case of learning neuron function in biology class.

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