On Effectiveness Evaluation of Innovative Teaching Techniques- A Case Study in Engineering Education

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Abstract

The accelerated global competitiveness and rapidly increasing level of higher education have necessitated implementing innovative ways and novel techniques to facilitate teaching and learning in engineering education. This not only ensures better understanding and learning of the students but also saves time and efforts, and enhances the success rates to maintain high throughput. The present paper discusses the evaluation of the effectiveness of some innovative teaching and learning techniques in the form of feedback analysis of the students. Some innovative and emerging techniques such as mind mapping, flipped classroom teaching, digital stories, and problem and project based learning etc. have been used while teaching manufacturing system design subject. A feedback questionnaire with a total of fifteen questions on the effectiveness of the applied teaching and learning techniques was developed and distributed to the students for anonymous feedback. The analysis of the feedback revealed that almost 90 % of the students who participated in the survey agreed that the techniques benefited them intensively. A detailed quantitative analysis of the feedback is presented in this paper. The paper aims to promote these innovative teaching and learning techniques, and to encourage academic community to adopt these to further facilitate their students.

Keywords
Education, Engineering, Learning, Teaching

1. Introduction

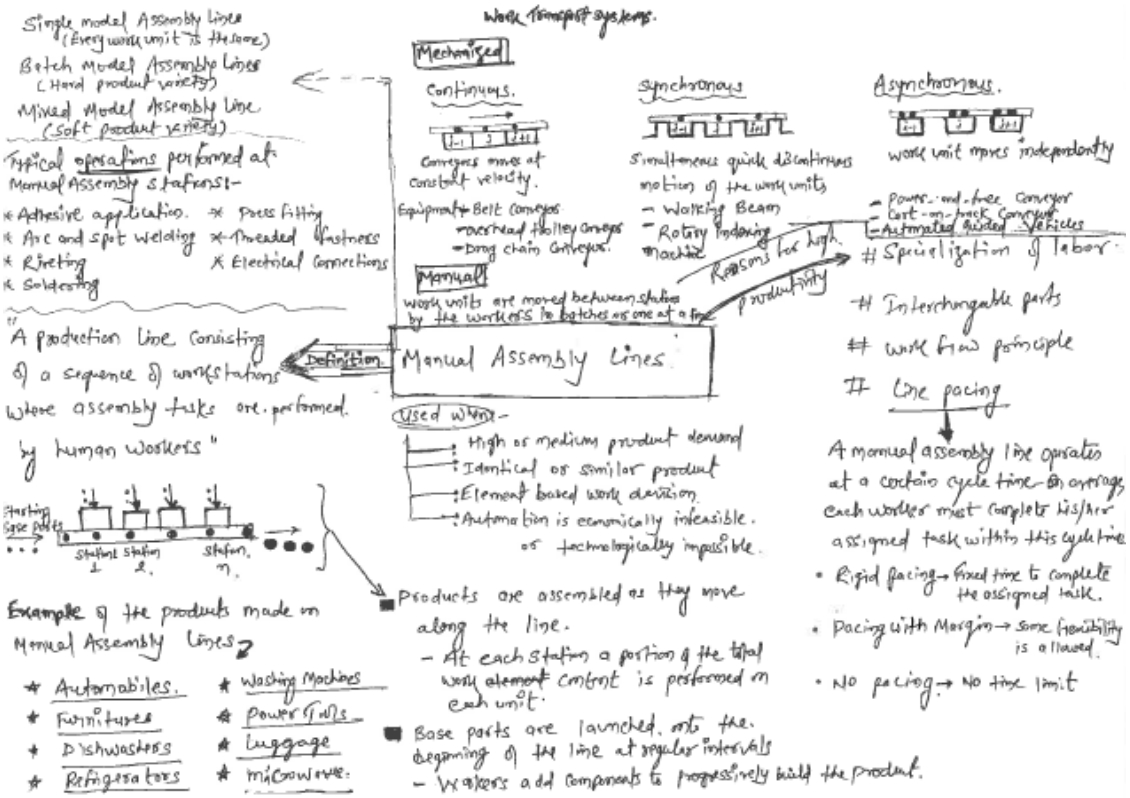
Using innovative teaching and learning techniques is the major requirement of the current education system globally. For the required transformation in higher education system, flipped classroom teaching, e-learning, virtual labs, and project and problem based learning etc. techniques are being given considerable importance these days. The role of information and communication technologies (ICT) has been found very effective for better understanding and enhanced learning of the students (Gupta et al., 2019; Kabouridis, 2008; Sukumaran and Dhandabani, 2014). In this era of the forth industrial revolution (Industry 4.0), the adoption and effective use of the aforementioned and other innovative techniques are required to be encouraged to build industry 4.0 ready engineers. To fulfill the industry 4.0 requirements, excellence in engineering education calls for a transformation from traditional backpack and chalk-board classroom based education to engineering education 4.0. Engineering education 4.0 is a package that consists of many novel teaching and learning techniques integrated with information and communication technologies for quicker learning at their own pace and convenience.
Flipped classroom teaching is one of the innovative teaching techniques where lecture or classroom time is spent in assimilation i.e. activities and interactive discussions, and the information transmission where students assess the lecture videos and materials, is done outside before coming to class (Wilson, 2013; Velegol et al., 2015). The students gain first exposure to the topic before class. Beyond the traditional teaching, the students are exposed to problem solving and critical thinking, leading to deeper understanding in the flipped classroom teaching. There has been an extensive research conducted on the implementation and effectiveness of flipped classroom teaching technique. In an interesting study, a substantial increase in student participation, engagement, learning, and class attendance was observed after using flipped classroom technique (Lucke et al., 2017). In a fluid mechanics course in engineering education, the flipped class room was successfully applied and effective results were observed (Orlando

et al., 2017). A comparative study between traditional and flipped classrooms was conducted by (Findlay-Thompson and Mombourquette, 2014). They found mixed views of the students and identical academic outcomes between traditional and flipped classrooms. Similar study conducted by (Shinaberger, 2017) identifies flipped classroom teaching as a viable alternate to the traditional teaching due to its profound benefits in terms of increased student engagement and helpful for the students who often missed the class etc.
ICT interventions have been found significantly effective in engineering education (Maldague et al., 2016). ICT based education stimulates learning motivation and eventually turns out in improved learning outcomes. E-learning, online blended learning, virtual labs, game based education, and e-assessment etc. are being extensively incorporated in higher education institutes and universities.
One of the important teaching tools, mind map, is a creative and effective representation of a particular topic to precisely describe it in a way which is easy to grasp, remember, and revise (Lin et al., 2009; Sbenaty, 2005). Mind map is a natural function of the human mind, and therefore promotes cognitive learning. Furthermore, it is easy to understand, its contents are easy to remember and recall, and hence extremely helpful for revision purposes. The central theme i.e. subject of attention is displayed at the center of the mind map, from which various branches holding key words are drawn to form a connected nodal structure depicting other contents. The paper showcases an example of mind map (see Fig. 1a) developed by the author for a particular chapter of the subject/module taught. There are numerous studies available on advanced learning of the students via mind maps in engineering education cases (Lin et al., 2009; Lin and Chuang, 2014; Turns et al., 2000). All of them identified mind maps as an efficient tool for student's learning and preparation purposes. One step further, the students of engineering were assigned to develop mind maps in system dynamics course for better understanding and enhanced learning (Woradechjumroen, 2018). Problem based learning, project based learning, and CDIO (conceive, design, implement, and operate) techniques have been found appropriate for redesigning engineering education (Crawley et al., 2007; Perrenet et al., 2000; Rios et al., 2010). Their role in developing critical thinking and problem solving skills has been proved many times by researchers and educators. However, the acceptance and dissemination of problem based learning approach in engineering domain are still scarce. Designing and formulating problems in problem based learning is an important and critical task, because problems must suit the requirements of learning objectives, skill and competency building, along with fulfilling the course contextual requirements. A problem based learning approach has also been followed in the present work while implementing innovative teaching techniques. Implementation of the aforementioned innovative techniques in the BEngTech module manufacturing system design, and evaluation of student's feedback on them is discussed in detail in the next section.

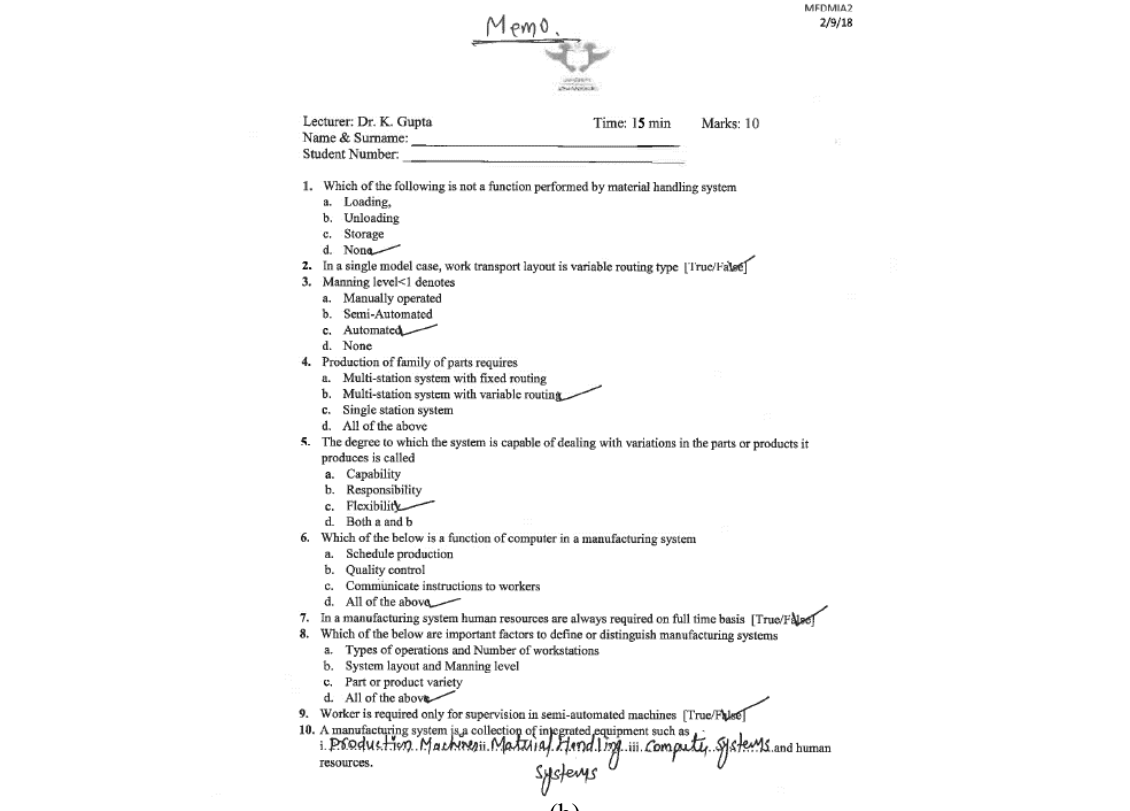
2. Evaluation and Discussion

The survey was conducted after the students were done with their semester activities. The purpose of innovative teaching techniques effectiveness survey was to gather honest, anonymous feedback from the students regarding their experiences, understanding, and benefit gained from the teaching techniques. The questionnaire was distributed to BEngTech second year students of Industrial Engineering during a contact session of manufacturing systems design module. The questionnaire consisted of a total of fifteen mandatory quantitative questions. The questionnaires were completed by a total of twenty six students that was the eighty percent student strength of that class in that module.
The following response set was used by the students to respond the questions asked:

5 Strongly agree
4 Agree
3 Disagree
2 Strongly disagree
1 Not applicable



(a)



(b)

Figure 1 Samples of (a) mind map, and (b) MCQ test developed by the lecturer

Figure 2 is the graphical presentations of the feedback results i.e. student responses. Table 1 presents the record of percentage and number of student responses for all question categories. The analysis of student feedback indicates that almost 95% students were agreed and strongly agreed that they found implemented innovative teaching techniques very helpful for their understanding of the module contents, learning, and preparation for exams. All students responded positively for the statement 'the innovative teaching techniques used by the lecturer enhanced my learning'.

Lecturer also found ease to explain the contents while teaching with the aid of these techniques. Under the flipped classroom teaching, since the beginning of the semester, lecturer used to put the lecture slides and relevant teaching and learning materials on the online Black Board for the students to access the material beforehand. The messages were used to be communicated to the students regarding commencing of every new unit, so that they can go through the contents before actual lecture. It helped the lecturer greatly, as the students were known the topics and contents, due to this the time taken in explanation reduced and the lecturer could get time to focus on some extra activities such as student practice, assessment using objective tests, and some problem based learning activities. Providing short notes in the form of mind maps (all contents of a chapter on a single page) at the end of every chapter ensured quick revision and learning of the students (See Fig. 1). Multiple choice questions (MCQ) based objective tests after every chapter were also given to the students for their practice and to examine their understanding and learning. The aforementioned materials were communicated them via online Black Board system, so that they can access at their pace and convenience. Moreover, some problem based learning activities were also conducted during the time saved after flipped classroom implementation. The students were assigned some problems regarding design of various manufacturing systems. Essential building block, parts, and components of manufacturing systems and some design examples were already communicated through lecture material which they accessed before coming to the class. In the class, students were asked to design some manufacturing systems using the knowledge gained from lecture material. That is how competency building and problem solving and critical thinking skills were developed.

Regarding qualitative feedback, some comments and suggestions were also provided by the students. Some anonymous examples are shared here as under:

- "Lecturer helped us by making mind maps and summarizing the notes he explains and all the concepts".
- "The teaching techniques work, they help our learning".
- "The innovative techniques used by the lecturer are very effective but can be amended and improved".

Overall, it can be stated that the students accepted the lecturer's teaching practice inclusive of these innovative techniques, and interestingly followed the lecturer's instruction to adopt, participate, and contribute for the successful implementation of these techniques for their own benefits.

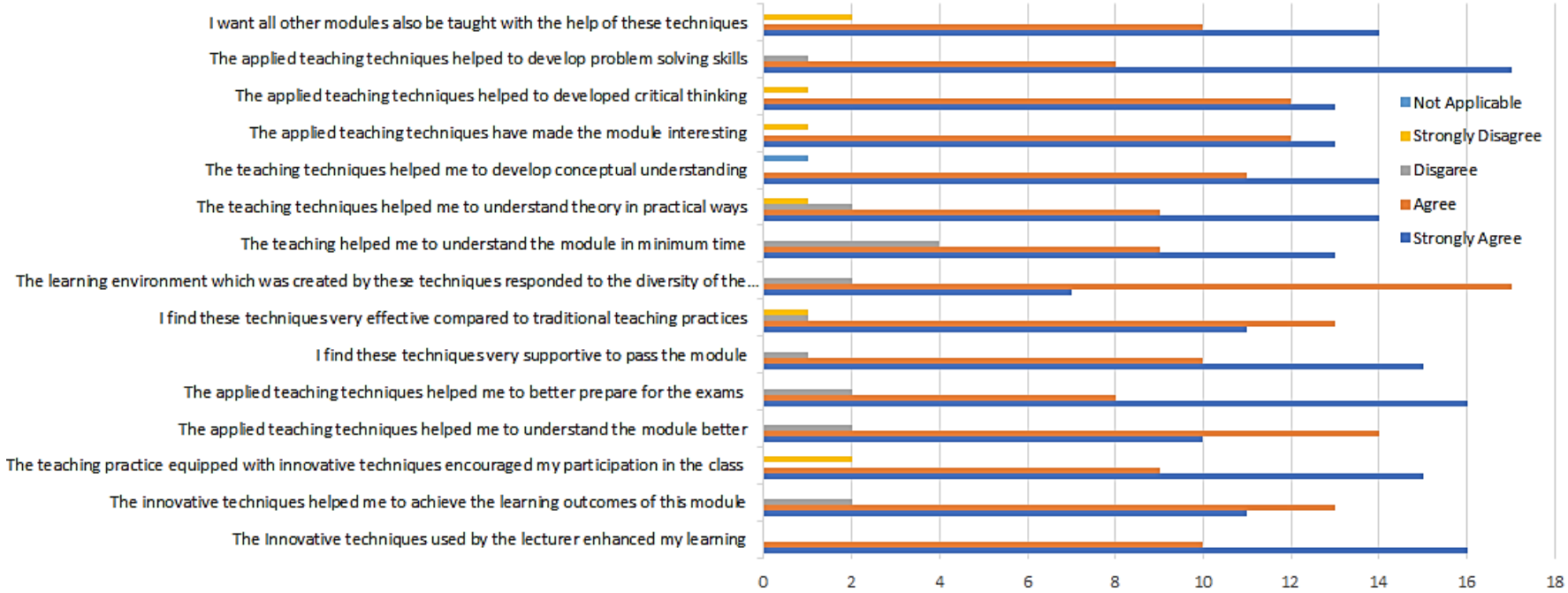


Figure 2. Graphical analysis of the student responses

Table 1 Question statements distribution on effectiveness of teaching and learning techniques

QUESTION STATEMENTS	Not applicable	%	Strongly disagree	%	Disagree	%	Agree	%	Strongly agree	%
	N	1	N	2	N	3	N	4	N	5
The Innovative techniques used by the lecturer enhanced my learning							10	38.46	16	61.54
The innovative techniques helped me to achieve the learning outcomes of this module					2	7.69	13	50	11	42.31
The teaching practice equipped with innovative techniques encouraged my participation in the class			2	7.69			9	34.62	15	57.69
The applied teaching techniques helped me to understand the module better					2	7.69	14	53.85	10	38.46
The applied teaching techniques helped me to better prepare for the exams					2	7.69	8	30.77	16	61.54
I find these techniques very supportive to pass the module					1	3.85	10	38.46	15	57.69
I find these techniques very effective compared to traditional teaching practices			1	3.85	1	3.85	13	50	11	42.31
The learning environment which was created by these techniques responded to the diversity of the students					2	7.69	17	65.38	7	26.9
The teaching helped me to understand the module in minimum time					4	15.38	9	34.62	13	50
The teaching techniques helped me to understand theory in practical ways			1	3.85	2	7.69	9	34.62	14	53.85
The teaching techniques helped me to develop conceptual understanding	1	3.85					11	42.31	14	53.85
The applied teaching techniques have made the module interesting			1	3.85			12	46.15	13	50
The applied teaching techniques helped to develop critical thinking			1	3.85			12	46.15	13	50
The applied teaching techniques helped to develop problem solving skills					1	3.85	8	30.77	17	65.38
I want all other modules also be taught with the help of these techniques			2	7.69			10	38.56	14	53.85

3. Conclusions

Various innovative teaching techniques and a case of their implementation and effectiveness evaluation are discussed in this paper. The package of learning techniques included mind maps; flipped classroom teaching; digital story, videos, and animations based lectures, and project and problem based learning activities. The analysis of the students feedback on a questionnaire based survey was found encouraging. The following conclusions can be drawn from this work:

- A majority of the students were agreed that innovative techniques used by the lecturer benefited them at a large extent.
- Use of videos, animations, and posters greatly helped to reduce the time taking for content explanation.
- It is concluded that innovative techniques based teaching practice can be a viable substitute to traditional backpack and classroom based teaching for better understanding and enhanced learning.
- Suggestions based on amendments and further improvement in the innovative techniques were also taken into account.

Avenues for future work include extension of digital story for other chapters and modules, increasing problem and project based learning activities, developing animations and videos, and using gamification techniques.

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Biography

Kapil Gupta is working as Associate Professor in the Dept. of Mechanical and Industrial Engineering Technology at the University of Johannesburg. He obtained Ph.D. in mechanical engineering with specialization in Advanced Manufacturing from Indian Institute of Technology Indore, India in 2014. Advanced machining processes, sustainable manufacturing, green machining, precision engineering and gear technology are the areas of his interest. He has authored several SCI/ISI Journal and International Conference articles. He also authored and edited 10 international books on hybrid machining, advanced gear manufacturing, micro and precision manufacturing, and sustainable manufacturing with the renowned international publishers. He has also successfully guest edited special issues of a Scopus indexed journals and he is currently editing a series of handbooks on Advanced Manufacturing as a series editor. He is a recognized reviewer of many international journals and in the advisor/technical committees of international conferences. He has also delivered invited speeches in international conferences and symposiums, and seminar talks at international universities. Kapil Gupta is a NRF [National Research Foundation] rated Researcher in South Africa. Currently, he is supervising some postdoctoral fellows and postgraduate students who are busy conducting research in advanced manufacturing and industrial engineering fields. He has obtained PG Diploma in higher education and conducting research in engineering education. He is working on implementation of innovative teaching techniques for the enhanced learning of engineering students. Recently, he also developed a manufacturing engineering virtual lab.