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New Approach to Teaching Engineering Drawing to Engineering Students

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Learning Objectives

- Implement a new method of teaching engineering drawing to first year students based on 3D modeling.
- Evaluate the new method of teaching engineering drawing compared to conventional 2D based approach.
- Apply techniques to build competency in 3D modeling using Autodesk Fusion 360 for first year engineering students.
- Understand the importance of multidisciplinary case studies for effective teaching of engineering drawing.

Description

The learning needs of Generation Z is significantly different from those of millennials and the generations before that. The challenges facing the current generation, as described in the United Nations Sustainable Development Goals, require multidisciplinary solutions and creative thinking. The conventional approach of teaching and learning engineering drawing, using the standard 2D projections, falls short in developing industry standard modeling skills which are 3D based. This presentation, therefore, provides an alternate approach of teaching engineering drawing to first year engineering students using 3D modeling with Autodesk Fusion 360. The approach enables students to develop 3D model of objects and generate the 2D projections from the developed 3D model. In the process, students gain competency in 3D modeling using Fusion 360. The content developed for this approach are multidisciplinary and based on activity-based learning. An outcome-based learning approach is adopted to sync the objectives, content, and assessments. The presentation provides details of the feedback received from three categories of users of this approach; students who have completed engineering drawing using conventional approach, freshers who have no prior engineering drawing experience, and faculty who have handled engineering drawing in conventional approach. The feedback points towards significant advantages in adopting the new approach of learning engineering drawing.

Speaker(s)

Mr Sharad Marathe is the President and CEO of Universal Technical Systems, Inc. Universal Technical Systems, Inc. (UTS) is a software products and custom software development

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company. It is a privately held US Corporation, established in 1984 and headquartered in Loves Park, Illinois. UTS is part of a family of companies, including Universal Technical Systems (Europe) Ltd, based in the UK and Universal Technical Systems (India) based in Pune and Gurgaon in India. Mr Sharad Marathe is also the Chairman of a task force set up by AYUSH Ministry, Government of India. Mr Marathe has completed his master's degree in business administration and Management from the University of Wisconsin-Oshkosh. He also possesses a master's degree in engineering Mechanics from Michigan Technological University. He is currently guiding Engineering Colleges/Institutions in implementing NEP 2020 curriculum in Engineering Education.

Dr Rio D'Souza has worked in the field of engineering education for more than 25 years in various capacities, both academic, as well as administrative. Currently, he is the Principal of St Joseph Engineering College, Mangalore, India. His research interests include evolutionary computing, cloud computing and engineering education. Dr D'Souza is a Life Member of Indian Society for Technical Education (ISTE) and Advanced Computing & Communications Society (ACCS). He is a Senior Member of IEEE and a Fellow of the Institute of Engineers (India). He has been included in the panel of International Experts on Engineering Education by the Indo-Universal Collaboration on Engineering Education (IUCEE) and has conducted Pre-Certification Workshops for the IUCEE International Engineering Educator Certification Program at several colleges in India. Recently, he was awarded by IUCEE as an Outstanding Institutional Leader for the year 2019.

Introduction

In India, Engineering Drawing is a mandatory course offered to all engineering students irrespective of their disciplines. The subject is crucial in developing skills of visualization and modeling of engineering objects. The subject includes orthographic projections of points, lines, planes, and solids. Isometric drawings and development of lateral surfaces are also included. The course was designed to meet the conventional industry needs of 2D projections of components for manufacturing and construction plans. The generated elevations, plans, and profile views provided the engineers with information needed for machining and fabrication. Assembly drawings of components were also developed in orthographic projections to enable desired fitting and alignments. While this continued, the industry moved on to computer aided drawings and 3D modeling. This enabled them to visualize the components and identify interferences more clearly. However, for a long time, academia in India continued to stick to 2D projections using the manual approach. In the mid 2000's, while most of the Universities switched over to Computer Aided Engineering Drawing, the approach was still based on 2D projections. This approach continues till date.

The student community has often expressed their difficulty in visualizing projections in 2D. While pedagogical interventions were made to solve this issue, it persists. The projection of lines inclined to both the projection planes is a common example, which students find difficult to visualize and solve. Also, the gap between industry requirements and academic outcomes have widened due to lack of 3D modeling skills in students. In this context, the presenters along with a team have developed a new approach of teaching engineering drawing that utilizes Autodesk Fusion 360 and a 3D based approach to address the issues highlighted above. A new set of course contents and pedagogy are developed and presented as an eBook in the UTS Learning Management Center.

The New approach

The new approach allows students to learn engineering drawing in 3D using the Autodesk Fusion 360 as the tool. Students will learn the 3D modeling commands, file handling, and get comfortable with Fusion 360, right in the first class of the course. Through, bite-sized videos, students learn to model objects in 3D. Multidisciplinary and real-world examples are introduced to generate interest among students from circuit-branches (Computer Science and Engineering, Electronics and Communication Engineering, and Electrical and Electronics Engineering) who otherwise fail to recognize the relevance of studying the course. The students will then be taught the process of generating 3D projections of the objects from the 3D model. This 3D model to 2D projections allows for easier and clearer visualization and grasping of engineering drawing principles. The competency developed by students in 3D modeling will enable them to be industry ready. While the relevance for 2D orthographic and isometric views in communicating dimensional features and constructional details is understood and appreciated by the students, they arrive at 2D views only after 3D modeling of the object and subsequent inspection.

Description of the New Approach

Novelty

The novelty in this new approach of teaching Engineering Drawing lies in the use of 3D modeling as the tool to teach all the concepts, from the outset. The students work on 3D modeling using Autodesk Fusion 360 right from the first day of the course. The course is designed to include industry standards in product development regarding the tool used, the projects involved, and the case studies. The new approach harnesses the power of technology for enhanced learning experiences of the students. Multimedia technology is used to bring diversity in the learning contents and pedagogies, such as, e-learning content, videos, animations, activities, case-studies, etc. In terms of pedagogy, the new approach uses outcome-based education, in which, the learning process is derived from pre-defined graduate outcomes that are based on industry requirements. This new approach can be utilized by apex bodies such as AICTE in faculty development programs for engineering and polytechnic faculty.

An example of the new approach

To illustrate the new approach, one of the case studies used in Module – 1 of the course contents, Introduction to 3D Modeling, is presented here. The common screw jack used to lift loads is made up of seven machine elements: Body, Nut, Spindle, Cup, Screw, Washer, and Tommy Bar. After going through the bite-sized videos that help the students understand the basic 3D modeling commands in Autodesk Fusion 360, as an exercise, they take up a hands-on work of 3D modeling a screw jack. With the aid of concise and precise videos and reading content, all seven elements of the screw jack will be modeled as shown in Fig. 1.

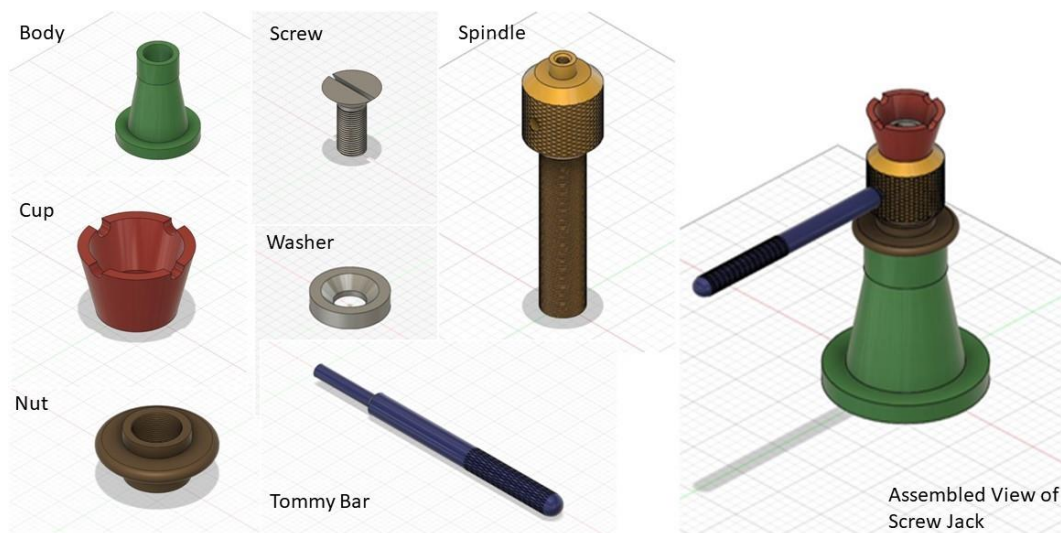


Fig. 1: 3D Modeling of Screw Jack

From the 3D model thus obtained using Fusion 360, students will proceed to extract the 2D Projections and Isometric views. The process of extracting the 2D views is taught to using both videos and through step-by-step written instructions. This is the fundamental technique adopted across all modules in this new approach of teaching engineering drawing to first year engineering students. The extracted 2D views and isometric view of the screw jack is presented in Fig. 2.

While the conventional teaching method of engineering drawing stops at the projection views, in this new approach, students are also taught the process of converting the 3D model to an .stl file, obtaining gcode, and developing a prototype using additive manufacturing (3D Printing). This process is explained through the students to video content and step-by-step written instructions as well. The 3D printed model and the virtual model are presented in Fig. 3.

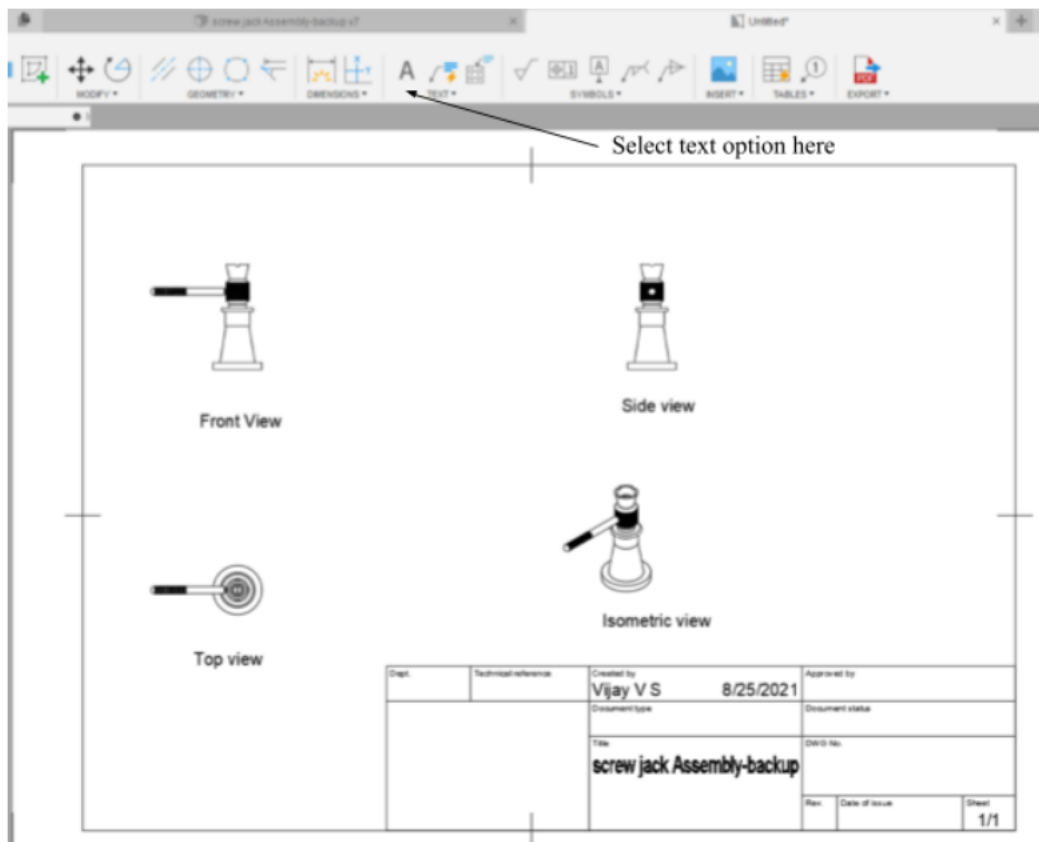


Fig. 2: Orthographic projections and Isometric Views of Screw Jack extracted from 3D Model

The Learning Management System

The Learning Management System utilized to host and manage the learning content developed using this new 3D to 2D approach of engineering drawing is the UTS Learning Center. The learning content developed by the team is integrated into UTS Learning Center. This LMS can be used for deploying eBooks and other online learning content for use by in a self-paced learning mode. The LMS is developed by Universal Technical Systems, Inc. (UTS), which is one of the two partnering organizations in the development of this new content. The content developed for this engineering graphics course is hosted as an eBook in UTS and offers students an early start to explore learning through MOOCs which has become the norm in today's education system.

A screenshot of the hosted content in UTS is shown in Fig. 4.

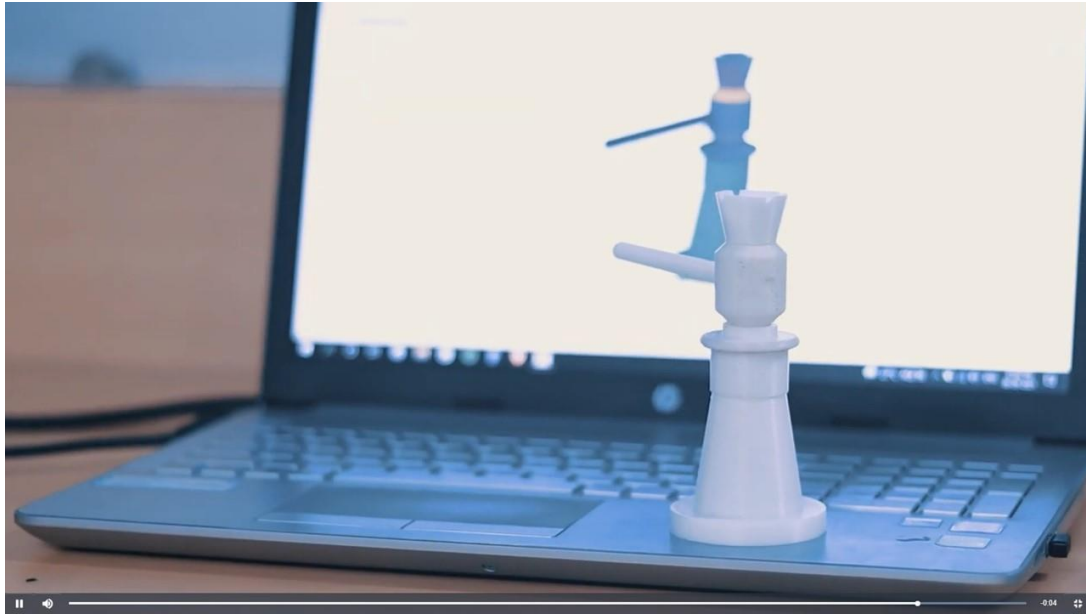


Fig. 3: 3D Printed model of scaled-down version of Screw Jack

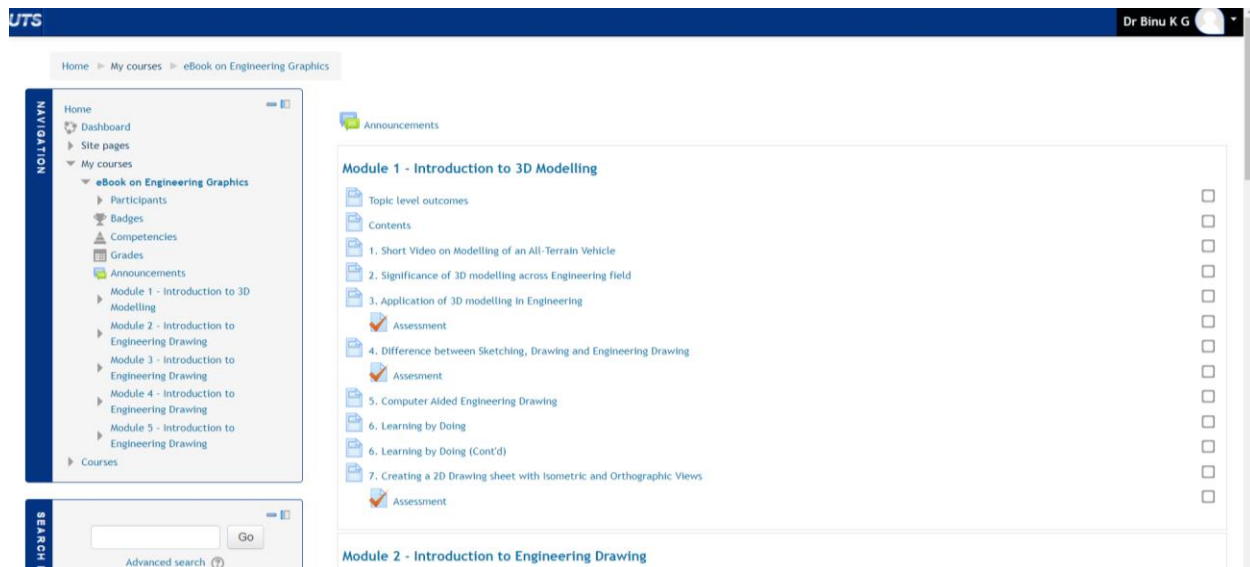


Fig. 4: Screenshot of UTS Learning Center highlighting the contents of Module - 1

Syllabus and Structure of Contents

The syllabus for the course on engineering drawing is derived from the model syllabus prescribed by AICTE. While no major changes are made in the syllabus, the focus is on the pedagogy and approach of uncovering the syllabus for the students. As described earlier, a 3D to 2D approach is adopted and the pedagogy relies on activity-based learning using Autodesk Fusion 360. This approach also provides ample scope for implementing Problem Based Learning due to the hands-on mode of learning process being implemented.

The Syllabus

The syllabus is categorized into five modules. The details of the syllabus are described below.

1. Module 1: Introduction to Engineering Graphics and 3D Modeling

Students realize the significance of 3D modeling. They develop working knowledge on Autodesk Fusion 360. They also learn prototyping using 3D printer.

2. Module 2: Orthographic Projections of Points and Lines in 3D

Students understand orthographic projections. They learn to develop projections from 3D models for points and lines.

3. Module 3: Orthographic Projections of Planes and Solids in 3D

Students develop 3D models of real-world applications of planes and solids and obtain their 2D projections.

4. Module 4: Isometric Projections in 3D

Students develop isometric projections from 3D models of solids.

5. Module 5: Development of lateral surfaces

Students develop lateral surfaces of right regular prisms, cylinders, pyramids, and cones.

The contents in each of the above module is structured in a uniform fashion with diverse learning materials. The main features of each module are listed below.

1. Topic Level Outcomes (TLOs): Every module begins with a description of the expected outcomes that are measurable in terms of students' learnings. This is in line with the Outcome Based Education model (OBE). The learning content constituting the modules are derived from the TLOs that are defined.

2. Impetus Video: An impetus video is provided at the beginning of each module to help students realize the significance of the topics that are dealt with. The video consists of real-world applications of engineering principles, that are aesthetically designed to attract the students' attention and motivate them to explore more about the topic. As an example, the impetus video of module-1 aims to emphasize the significance of engineering drawing to students. The video, therefore, uses the complete design of an All-Terrain Vehicle (ATV) to demonstrate the importance of part modelling in 3D and 3D assembly of the parts. Screenshots of a sample video is provided in Fig. 5.

3. Reading Contents: The principles of engineering drawing, such as orthographic projections, projection planes, apparent lengths, and angles, etc. are explained through concise reading contents. The use of illustrations and sketches aid in the learning process of the students. While the reading contents are not extensive, they are engaging and motivates the students to explore further about the topic.

4. Assessments: Formative assessments in the form of quizzes are included at multiple sections throughout the modules.



Fig. 5: Screenshot of an impetus video from Module -1 (ATV)

5. **Activity Based Learning:** Hands-on guided activities are included for students to develop their 3D modeling skills while learning various principles of engineering drawing. Bite-sized demonstration videos are provided to handhold the students as they begin using 3D modeling in Fusion 360. Multiple activities are designed for each topic being covered to reinforce the learning.
6. **Case Studies:** Real world applications are provided as case studies for students to understand the relevance and standards of engineering drawing.

Feedback on the New Approach

The new approach of learning engineering drawing and the contents developed were deployed among stakeholders and their feedback were obtained. Feedback was received from three groups of users. Group – 1 users were students who have previously undergone a course on engineering drawing using the conventional approach. Group – 2 users were fresh students who have no previous exposure to engineering drawing. Group – 3 users were faculty from various disciplines of engineering. Feedback instruments were specifically designed for all three groups to assess the benefits, user experiences, impact, and overall quality of the approach and contents.

The feedback instruments were supplied to the users in a laboratory of the partnering institution and the access to the content hosted in UTS were provided. Access to AutoCAD Fusion 360 was also provided to the participants for hands-on work as explained in the eBook. The observations and inferences from the Feedback are summarized below.

Feedback from Group – 1

In Group – 1, a sample of 18 students who have completed a course on engineering drawing using the conventional approach experienced the contents and provided their feedback. The team of faculty involved in the development of the content were available in the lab to clarify the doubts of the students and facilitate the overall feedback process.

Feedback Instrument

The designed feedback instrument was deployed among the participants as a Google Form. The instrument was designed as a Likert scale of 5. The questions in the instrument are provided below.

1. The approach followed in this module was completely different from what I experienced when I learnt this subject earlier.
2. The approach followed in this module made it easy for me to grasp the topic at hand.
3. The theoretical concepts and practical exercises were well-balanced to optimize learning.
4. How do you rate the motivational video in terms of its relevance to the module?
5. How do you rate the questions/ problems related to practical applications given in the module?
6. After going through this module, the learning objectives stated at the beginning were met.
7. The continuity between various units of the module was well-maintained.
8. The module helped me visualize and relate to the topic at hand.
9. How do you rate the ease-of-use of the module in terms of commands/instructions?
10. How do you rate the overall quality of your learning experience when using this module?

Key Observations

The responses received from the participants were largely positive. Some of key results of the survey are listed below.

- An average of 96% participation ratings were four and above.
- It was observed that 89% of respondents felt that the theoretical concepts and practical exercises were well-balanced.
- 89% of respondents felt that the questions / problems related to practical applications were excellent.
- 58% of respondents felt that the module was excellent in visualizing and related them to the topic at hand.
- All participants felt that the overall quality of the learning experience is excellent.

Some of the prominent comments received from the participants are listed below.

- Easier visualization.
- Provides an answer to the question “why do we need to learn this?”
- Effective approach.
- Very helpful for learning projection of points and lines, as it was difficult using the old approach to visualize without 3D models.
- The concepts were made easy to understand with the help of illustrations and activities.

- Helps in describing everything with a reference, which leads to better communication of design ideas.
- It took some time for me to understand the flow of the learning material.
- Fusion 360 is very easy to learn for beginners.
- This method is helpful and intuitive for anyone learning CAD as a beginner. Giving open-ended assignments will be helpful.

The survey also indicated that the new approach was significantly different from the conventional approach of teaching engineering drawing. For the statement - *This new approach to Engineering Graphics is completely different from what I experienced when I learnt this subject earlier.* The results obtained are shown graphically in Fig. 6 below.

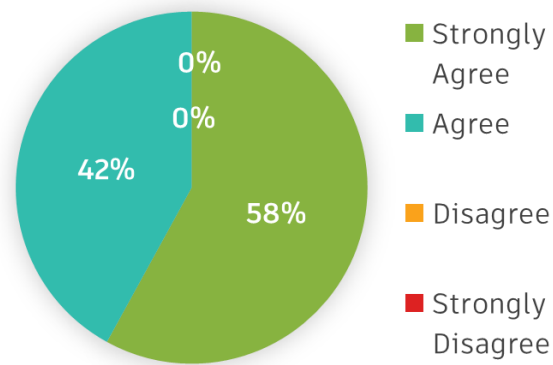


Fig. 6: Ratings for significant difference in conventional and new approach

This result coupled with the high ratings for every question point towards enhanced learning and satisfaction among the students.

Feedback from Group – 2

In Group – 2, a sample of 12 students who have had no prior exposure to engineering drawing experienced the new approach and content and offered their feedback. Supported by the faculty team, the students were taken through the course content and feedback were documented.

Feedback Instrument

The designed feedback instrument was deployed among the participants as a Google Form. The instrument was designed as a Likert scale of 5. The questions in the instrument are provided below.

1. I was able to follow the instructions and material provided easily, without any ambiguity or confusion.
2. I was able to grasp the topic at hand and visualize each step easily.
3. The theoretical concepts and practical exercises were well-balanced to optimize learning.
4. How do you rate the motivational video in terms of its relevance to the module?
5. How do you rate the questions/ problems related to practical applications given in the module?

6. After going through this module, the learning objectives stated at the beginning were met.
7. The continuity between various units of the module was well-maintained.
8. The module has created an interest in me to learn more about the topic at hand.
9. How do you rate the ease-of-use of the module in terms of commands/instructions?
10. How do you rate the overall quality of your learning experience when using this module?

Key Observations

The responses received from the participants were mixed. Some of key results of the survey are listed below.

- An average of 76% participation ratings were four and above.
- It was observed that 91% of respondents felt that the theoretical concepts and practical exercises were well-balanced.
- 92% of respondents felt that the questions / problems related to practical applications were excellent.
- 91% of respondents felt that the module has created an interest in them to learn more about the topic at hand.
- 75% of respondents felt that the overall quality of the learning experience is excellent.

Some of the prominent comments received from the participants are listed below.

- Videos were useful in grasping the software.
- Subtitles needed.
- The content was a little hard initially but was easy to use later.

Responses of two key statements that analyzes the efficiency of the approach among new users are presented below.

Statement – 1: *I was able to follow the instructions and material provided easily, without any ambiguity or confusion.*

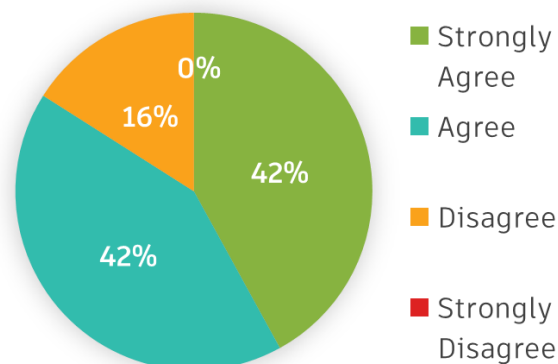


Fig. 7: Ratings for easy comprehension of contents

While 84% participants felt that the contents are easy to grasp, remaining students felt that the contents need improvement. This is especially true for new students, as they require more guidance and support.

Statement – 2: *I was able to grasp the topic at hand and visualize each step easily.*

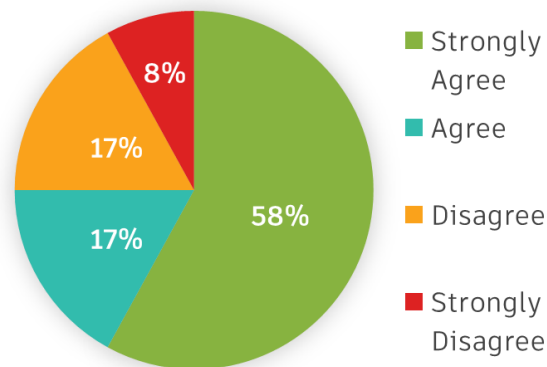


Fig. 8: Ratings for grasping and visualization

75% percent students agreed that the contents were easy to grasp and visualize, the remaining participants felt that the contents need to improve. Overall, for fresh students, the content may be slightly difficult and needs to be modified to suit their requirements.

Feedback from Group – 3

In Group – 3, a sample of 20 faculty experienced the new approach and content and took the survey. Supported by the faculty team involved in the development of the content, the participants were taken through the course content and feedback were documented.

Feedback Instrument

The designed feedback instrument was deployed among the participants as a Google Form. The instrument was designed as a Likert scale of 5. The questions in the instrument are provided below.

1. The approach followed in this module was completely different from what I experienced when I learnt this subject as a student (and as a teacher).
2. The approach followed in this module made it easy for me to grasp the topic at hand.
3. The theoretical concepts and practical exercises were well-balanced to optimize learning.
4. How do you rate the motivational video in terms of its relevance to the module?
5. How do you rate the questions/ problems related to practical applications given in the module?
6. After going through this module, the learning objectives stated at the beginning were met.
7. The continuity between various units of the module was well-maintained.
8. The module helped me visualize and relate to the topic at hand.
9. How do you rate the ease-of-use of the module in terms of commands/instructions?

10. How do you rate the overall quality of your learning experience when using this module?

Key Observations

The responses received from the participants were mixed. Some of key results of the survey are listed below.

- An average of 82% participation ratings were four and above.
- It was observed that 62% of respondents felt that the theoretical concepts and practical exercises were well-balanced.
- 94% of respondents felt that the questions / problems related to practical applications were excellent.
- 69% of respondents felt that the module helped them visualize and relate to the topic at hand.
- 72% of respondents felt that the overall quality of the learning experience is excellent.

Some of the prominent comments received from the participants are listed below.

- Engaging content. Provides for effective self-paced learning.
- Effective pedagogy.
- Enables better visualization of the underlying concepts.
- The content was in a proper flow for students to understand. Specifically, the explanation of the theory and the 'learning by doing' concept is good.
- Graphical design and modeling can be understood easily by the students because of the visualization approach adopted".
- The drawback of classroom teaching is overcome. Students can go through the video multiple times based on their own pace.
- This type of learning promotes interdisciplinary collaboration in learning and promotes application in many fields.
- The overall content of this module is well developed. It would be better if the sketches provided are of more clarity.

The survey also indicated that the new approach was significantly different from the conventional approach of teaching engineering drawing as indicated by the faculty and few teachers who have taught the subject in recent times. For the statement - *The approach followed in this module was completely different from what I experienced when I learnt this subject as a student (and as a teacher)*. The results obtained are shown graphically in Fig. 9 below.

The results show that all the participants agree that the new approach of teaching engineering drawing is significantly different from the conventional approach. Along with the high ratings received from all participants, the survey adds to the overall feedback received from students about the benefits of this new approach.

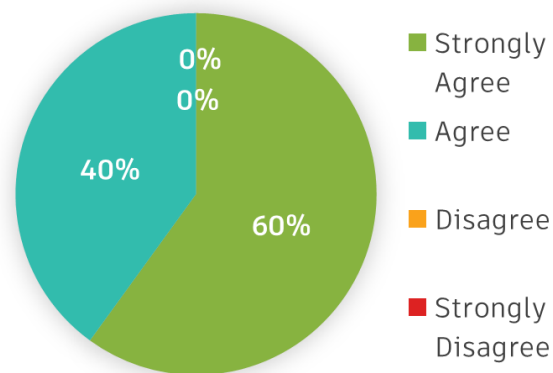


Fig. 9: Ratings for significant difference in conventional and new approach

Scaling Plans

The development of the contents and the feedback collection were carried out at the St Joseph Engineering College, which is the partnering institution to UTS in this endeavor. Going forward, it is planned to extend this approach to 14 more colleges / universities that are part of a pilot group of institutes focusing of new approach to implementation of NEP 2020.

The contents will also be revised as required, based on the broader feedback received from all stakeholders. Plans are in place to take the contents to industry partners and take their feedback and suggestions. The team also looks forward to work with AICTE to extend this method to many engineering colleges and polytechnics in India.

The team also aspires to further develop the process to link mathematical modelling using TK Solver and graphical modelling using Fusion 360 for other components of engineering curriculum.

Summary

Summarizing, the team is very encouraged with the responses of all stakeholders, received thus far. More work will go in to make the contents relevant to fresh users with no prior experience of engineering drawing. The contents are also being revised based on the feedback. The general feedback highlights the fact that students are more motivated to study engineering drawing in this new approach. The effort has helped the team believe that the new approach to engineering education is possible and is the way forward to make the students industry ready. The new approach has the potential for enhancing the employability of fresh graduates.