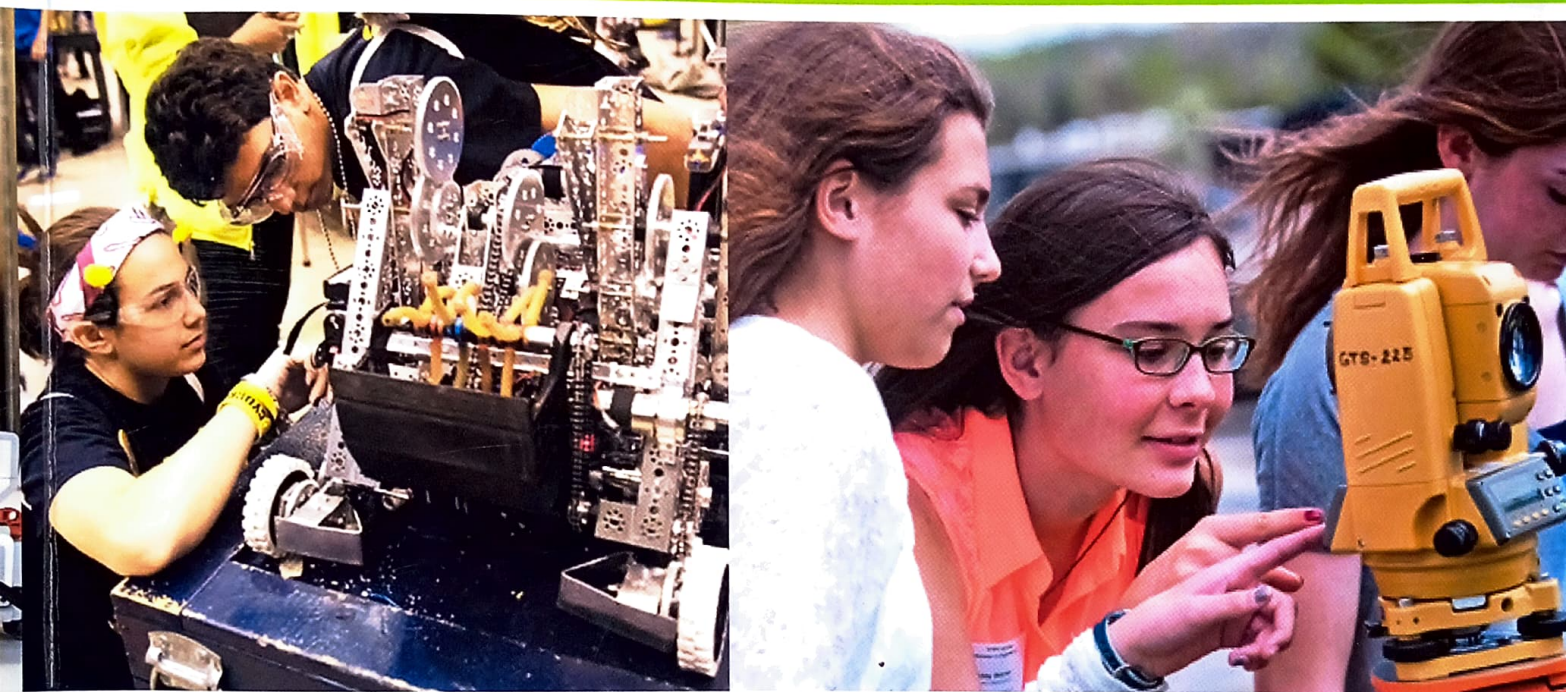


# JEET

Journal of Engineering  
Education Transformations



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## Editorial



**Dr. Mrs. Sushma Kulkarni**

A study, courtesy ZINNOV, shows that if we have 1000 females start their journey, 640 of them attend school, 377 of these girls get to college, 256 attend STEM courses (approx.), 217 of STEM trained women join the tech workforce, 88 quit within 10 years thus leaving 129 in the workforce (approx.). 8 women out of 88 come back as second career women (80 women lost). 26 out of 129 reach senior positions, 2 out of 26 reach the board room. More than that, only 14% start-ups' in the country are led by women leaders.

There is a leak at each stage, widening as we move up the career ladder. What should we do about this "Leaky pipeline"? We need to create a Self-sustaining ecosystem platform for women's advancement and inclusion. It's not a pretty picture, and if we wish to change this picture, we need to take special efforts to sow the seeds of leadership in women even as they are little children. The need of the hour is to identify and block the holes that make the pipeline leaky.

Thus the most important aspect is that they should know that there are women who have struggled hard and reached to top. Presenting role models to them will definitely prove a milestone in their outlook. I am happy to share that we have worked on compiling and presenting the journey of 30 women leaders to the top positions in India through a book titled "Rising to The Top: Indian Women STEM Leaders." This book focusses on highlighting the challenges faced by Indian women leaders to reach the top and sustain the position.

The book beautifully presents diversity in terms of geography of India, as each part has its own language, culture and tradition which impacts on the upbringing and the aspirations of a girl child in the family. We have included women leaders from STEM too. Another parameter, which we have considered, is that they are from different career verticals like Industry, Academia, Research, Politics and Entrepreneurship.

There are stories of small-town girls, of girls from very orthodox background, girls from big joint families, and also girls born to financial disadvantage.

Journey to the Top is tough and women need to be ready to face the societal challenges and pressures. Courage to work and take risk, belief in your own self and a vision are important component of women leadership. Sometimes Women have to fight against culture, tradition and society to pursue their dreams.

There are as many as 30 minds in the following pages whose powerful lives should enlighten you to the fact that there is a reason you are born a woman. It's time to acknowledge that your wings are splashed with beautiful colours and as you soar, the sky is your limit. So, build those wings strong and powerful and splash it with the colours of your choice. But don't forget to fill it with iron and bind it with the confidence that nature has built you with! Enjoy!

**Dr. Mrs. Sushma Kulkarni**  
Editor, JEET

# A Pragmatic Analysis of Mobile and MOOCs Based Learning Methods

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**Abstract** - With the increasing use of the Internet, education availability to large masses through online mode has become easy. The platforms for Massive Open Online Courses (MOOCs) like Udemy, Udacity, Edx, Coursera etc. and mobile learning technologies like mobile live video streaming system have evolved all over the world. Through these platforms it has become quite easier for the academicians to provide education. In several remote areas, the learners are not able to attend classroom teaching. But, with the help of emerging technologies like Electronic Learning (MOOCs) and Mobile Learning, many people can now learn things at any time from anywhere at free or very less cost. It also allows academicians to make their content and teaching skills reach everywhere. These technologies help both academicians as well as students. Various multimedia tools are also used for making out the content look attractive and interactive. Students join these courses to compete among themselves, gain knowledge and earn certificates. Almost every type of course is offered ranging from basic to specialization courses. These technologies are a boon to our learning culture. This paper makes an analysis of advantages and limitations of MOOCs based and mobile learning modes. This paper also

maps the findings with a survey on 770 students of Delhi NCR region (India). As in this era of technology we all see the future of education in MOOCs and Mobile based learning, hence the major findings of this work is to identify the gap in these modes based learning methodology. It will help the practitioners to improve the utilities from these modes of learning.

**Keywords** - Education; MOOCs; Mobile Learning; M-learning applications

## 1. Introduction

As the population is increasing rapidly, there is a need to provide education on a vast scale. But, providing face-to-face education (campus education) to everyone is not possible. So, a need to educate masses through online mode is felt. Boom in networking technology and availability of internet services can make this task easy. Also [1] states that social network sites (SNS) like Facebook, Twitter provide a common platform to share users' interests. This can group users with similar interests.

Today, the internet helps in providing education on a vast scale. It enables the instructors to provide education to a large mass efficiently and effectively. With the increasing number of MOOCs platforms and mobile technologies, the concern goes in analyzing how these can be helpful in providing education. There is a need to have an analysis of advantageous and disadvantageous features of MOOCs and mobile learning like mobile social presence of

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instructor[2]demographic differences[3] hint super posters [5], discussion forms, chat-rooms various evaluation systems learning through recorded video lectures mobile learning in rural areas learning in live video streaming various mobile built to support five themes namely:- administration, presentation, motivation, feedback and innovation of students. This analysis will help the course designers in making the course content and structure so as to have large knowledge gains of students after taking the courses.

This paper handles Section 2 giving an introduction about MOOCs and Mobile learning. Section 3 and 4 describe advantages and limitations of MOOCs and mobile learning technologies respectively. Section 5 states the future work needed to be done in some features of these technologies. Section 6 draws the conclusions that emerge from this survey study.

## 2. About Moocs And Mobile Learning

### A. Massive Open Online Courses (MOOCs)

The platforms like Udemy, Udacity, Edx, Coursera etc. provide online courses to a large number of people where learners go through the content at their own pace. There are many free or low cost platforms that allow students to attain knowledge and take the course of their own interest. These are the platforms where students are not forced to complete their respective degrees; instead, these are very helpful platforms which offer free education to those who are not able to take classes at institutes. Students register to MOOCs and provide a list of goals that they want to achieve during their stay in the course. At the end, they verify whether they have achieved the goals set by them at the beginning of the course. Also, a student is allowed to leave or drop a course without paying for any penalty. Those who complete the course curriculum on time are provided with the certificate of completion of the course. Fig. 1 gives an overall view of MOOCs.



Fig. 1. Overall view about MOOCs

### B. Mobile Learning (M-learning)

Almost everyone carries mobile equipment in today's world. M-learning is another way to provide distance education. Various applications are built on mobile which are helping to learn things. Mobile Technology can be used to make sure that knowledge is available to all at every moment of time. The whole essence of m-learning is shown in fig. 2.

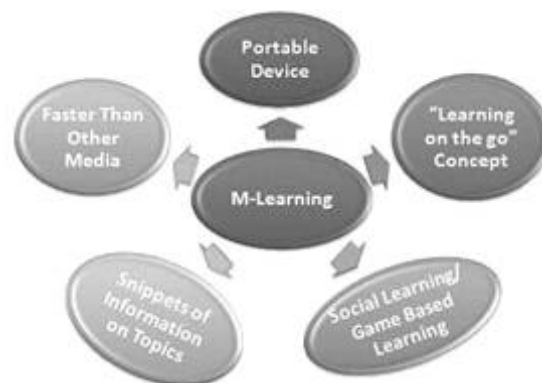


Fig. 2. Overall view about M-Learning

## 3. Advantages and Limitations of Moocs

### A. Advantages

There are several advantages of MOOCs. Some of them are discussed below.

#### 1) How students navigate through courses

MOOCs have a lot of advantages that help the students to understand the courses and achieve their goals in a better way. They also help the instructors to better design their course content and lay out a good course structure. The first step to make better MOOCs is to understand student prior skills, their demographics, their post-course goals and how they achieve their goals. A study is made on “prior skills and goals” of students registering for the course – “Mapping with Google” in MOOCs. It addresses how their prior skills affect their success in the course as well as how their goals affect their completion and dropout rates. Based on this study mainly four categories of students were identified –

- No shows – who only register the course but never come back even to see the course.
- Observers – who register the course just to see how a course at MOOC looks like?

- Casual learners – they take the course more seriously and cover some topics based on their interests.
- Completers – they complete the course, view lectures, do all assignments and projects on time, and earn a certificate of completion at the end of the course.

Students register to MOOCs from different age groups and different countries. Students should ensure that they are 'self-directed' and 'self-oriented' learners. But, some students are weak at taking things and defining a path by themselves. This situation makes them feel disheartened and ill-suited for taking the online courses. [29] Reveals the impact of MOOCs on the behavior and employment of self regulated learners. Describes the demographic differences among students to show how they navigate through MOOCs having these differences. The results reveal that older students follow a non-linear way (jumping back to lectures from assignments) while younger students follow a linear way (going through the course in a sequential manner). Students from countries like the USA where student-teacher ratio is low follow a non-linear way and act as “explorers” whereas students from countries like India/Kenya where student-teacher ratio is high follow a linear way and act as “observers”. Based on this mentioned point, we did a survey on 770 engineering students of Delhi NCR region (India). The results shown in Fig. 3 represent that the majority of the students want to learn new skills/want to complete their course. Many students proceeded directly to activities/exercises rather than the lectures/videos. If they were successful in those activities, then they jumped to next activities, otherwise they jumped back to videos. Students who completed activities as well as watching videos have a greater rate of completing courses than the students who did not watch videos.

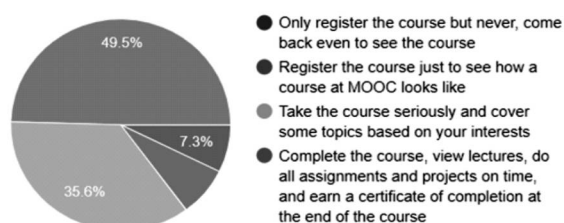


Fig. 3. Students navigation behaviour for MOOCs.

## 2) Video watching patterns

Contribution of videos and understanding how students learn from them is an important part while

studying features of MOOCs, but many students watch only videos and are not involved with any other activity like discussions, assignment problems. and make a study on how students interact with online videos and analyze student learning patterns through the videos. These studies have been conducted on four MOOCs of Edx namely Intro. CS & Programming (MIT), Statistics for Public Health (Harvard University), Artificial Intelligence (Berkeley University) and Solid State Chemistry (MIT).

In authors analyze video watching patterns of the students like which points of videos have dropouts and peaks. It analyzes student activities namely playing, pausing, replaying and quitting. It reports that long videos lead to higher dropout rates rather than short videos. This study highlights on five student activity patterns that explain peaks

- When a new study content is watched from beginning
- When someone misses on some content and replays that missed part
- When students learns from tutorials rather than entire lectures
- Watching and replaying a short segment again and again
- Repeating a part that is not explained through visuals.

It gives some suggestions for content developers to make shorter videos. It also gives suggestions for interface designers to provide markers to mark the peaks in videos so that the students can access interesting parts of videos in a non-sequential manner.

In a study is done to find what kind of videos help students to engage and learn more. The Student engagement is measured by engagement time which indicates the time spent by the student in watching a video. But it does not capture whether the student is giving attention or not. So, some of the findings and suggestions that arise from this study are:

- (a) Short videos, talking heads videos and videos where instructors speak at a faster rate are more engaging.
- (b) High production value might not matter i.e. the

instructors should teach by having direct eye contact.

(c) Table drawing where an instructor draws on a digital tablet is more engaging.

### 3) Various factors to capture students performance

There are so many resources for an online course. Now the question arises which of these resources is the most useful resource to recognize how well the students are doing in the course. [22] explores various aspects of mobile and accessible learning for MOOCs. In normal classrooms, instructors can easily identify how the students are getting engaged with their subject and other course material. It is easy as there is face-to-face interaction. But, in MOOCs it is extremely difficult for instructors to determine how learners are going with the course as there is no individual interaction. To know about the understanding of the students with the course, focuses on determining which information sources are the most valuable. Information sources being taken into account are: Grades for an assignment, Discussion forum activity and Chat logs. Data visualization is not done in MOOCs on a large scale, so in order to do so; this study has done 2 jobs: Metrics data and Survey. In Metrics data, 3 metrics tabs are used - Count of students who opened a subsection, Grade distribution per problem and Attempt distribution per problem.

In addition to metrics tab data, Survey monkey was used to conduct the survey. The survey asked the instructors which information sources they would use to know about the understanding of the users. Survey made use of the five visualization mock-ups.

Five visualization mock-ups used are: -

- Boxplot diagram of assignment grade distribution
- Stacked bar graph of grade distribution
- Line graph of forum
- Stacked bar graph of attempts distribution
- Stacked bar graph of views distribution

Metrics Tab results show that Metrics Tab was used by only 2 instructors. Both of them used an open subsection count graph to see how well the students are engaged with the course. Survey results show that the handiest activity is discussion forums and the

activity that shows very less student involvement is chat logs. The most common information sources are class surveys, forums and discussion with students and teaching assistants. Instructors found information about overall student performance relative to the class and the materials students interact with and for how long, as very useful. Visualization mock-up results show that visualization mock-up of assignment grade distribution is the most useful and understandable. Number of materials viewed by students was also useful information. Stacked bar graph of grade distribution was difficult to understand. Line graph of the forum was also not useful. Instructors felt that they could use visualization while the course was running as compared to preparing new material for a course. This concluded that assignment grades are not enough to know how well the student has done in the course; instead, discussion forum activity has proved a very useful source, whereas, chat logs are not that much useful.

### 4) Evaluation of open-ended questions

Now, coming to the evaluation part it is seen that closed ended questions are easy to evaluate as compared to open ended questions. Closed-ended questions like MCQs, True/False, Yes/No; provide a list of choices/answers to the respondents. Students are only allowed to answer the question from those options only. Open ended questions require the question to be answered in one word or one sentence without giving any options to the student. So, this makes the student think before answering the question. It allows the respondent to give that piece of information that he thinks is the correct explanation of the corresponding question. Thus, open ended questions are better than closed ended questions for learning purposes. But, in our survey we found that 81.2% students prefer objective based questions more effective as compared to subjective questions for evaluation. So, based on the above observation, some suggestions for the designing of courses like the videos should be made more interactive by including MCQs in between the videos rather than asking questions at the end of the video.

If open-ended questions are evaluated by instructors using flat assessment, where each response is to be marked one by one, then it will become time consuming. The study in open ended questions are assessed using an interface. In this approach students' responses are grouped into clusters and sub-clusters by making use of Machine Learning and Natural

Language Processing (NLP). Then these clusters are accessed by teachers through an interface/tool named “Power grading – A 'Power Tool' for grading”, which allows them to read, grade and provide feedback to a large number of responses at once. This interface has 4 divisions - 1st division has all the clusters indicating the answer keywords on the top of each cluster. If a cluster is selected, then its sub-clusters are seen in the 2nd division. 3rd division has all the individual answers of a selected sub-cluster. 4th division has options to mark clusters/individual answers as correct, partial, and incorrect and also give feedback.

If the instructor/teaching assistant feels that the cluster is correct/incorrect/partial by watching the keyword on the top of that cluster, then he marks that cluster accordingly, which leads to the evaluation of all the answers under that cluster. Also, feedback is done only once for a significant number of students. Assessment through interface is better than flat assessment.

Another study on evaluation, “identify-verify pattern/workflow” is carried out in It combines peer assessment and automated/algorithmic grading systems for open ended/short answer questions. This is done because peer assessment takes a lot of time of students in grading, if done in isolation. If algorithmic grading is done in isolation it searches for certain keywords and grades accordingly, thus ignoring students' understanding. In this workflow, algorithmic grading estimates how many peers are needed for assessment. Using the rubric key, different meaningful answers are identified by peers.

Results reveal that peers were more lenient than staff and understand ambiguous answers in a better way, as they also look for the concepts and understandings a student has acquired. They also get benefits in return as they also learn while evaluating. Identify-verify pattern is promising as it provides accurate results. With less number of raters, accuracy is maintained because the automated system generates confidence scores and assigns fewer raters for unambiguous answers. Although it takes more time to grade, it still provides more descriptive and accurate feedback to students.

## 5) Discussion Forums and Interaction with students

As MOOCs are free online courses, it is normal to say that the ratio of teaching staff to enrolled students reaches 1:5000 and thus, it becomes impossible for

instructors and TAs (Teaching Assistants) to have a meaningful interaction with the students and reply to each and every question for such a large number of enrolled students. Reports that those who post most frequently on the forums, called as superposters, result in high-value contributions towards making other students understand the course in a better concept. Super-posters make quantity as well as quality posts. Quantity is measured by the number of posts that are made by a student on discussion forums. Quality is measured by the number of votes on super-posters' posts. A measure of both quantity and quality is known as reputation. Many times it happens that students keep posting to forums asking their queries but the instructor may not be able to answer all the queries as they have limited time and have to handle thousands of students. Also, non-superposters reply less frequently or don't reply at all, so, in such cases, the role of super-posters is of great help to both instructors as well as students. Also in our survey as shown in fig. 4, we found that a large portion of students found the forums helpful and interactive.

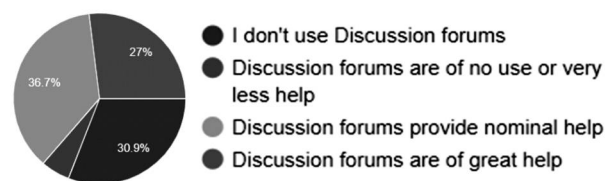


**Fig. 4 : Importance of Discussion forums in learning**

Participants' profiles and some social tools are delved into 2 built-in and 3 external tools were used to contribute to MOOCs. Built-in tools used are: Q&A and Forums. External tools used are Facebook, Twitter and Mentor-Mob. 339 students posted 604 posts on Q&A whereas 800 students posted 2819 posts on Forums. Among external tools, Facebook had the highest impact, Twitter had a moderate impact and Mentor-Mob has a very low impact. So, forums came out to be the best social tool to contribute to the MOOCs.

The study in works towards driving an improved quality learning process via massive online open courses. It focuses mainly on the sharp decline rate of interaction on these courses with time and facilitates easy navigation of relevant information through overloaded discussion forums. It generates an algorithm model to efficiently choose and classify threads which filter out the “noisy discussions” and thereby rank them in relevance order for appropriate course related discussion. It devises an algorithm for

discussion threads on forums which simultaneously works for effectively finding classifiers, extracting relevant topics from the discussions and ranking these in relevance order.

It first of all refines the data set by categorizing the courses as quantitative, non-quantitative, vocational, non-vocational and discussions into three types – small talk, course logistics and course specific discussions. It then studies the dynamics of small talk over time and concludes that for vocational courses it decreases steeply but for non-vocational courses like Humanity it maintains the speed throughout the course and decreases very gradually. The regression model presents a statistical analysis of different factors, for example that though the teaching staff posts increases the volume of discussion, it is not helpful in reducing the decline rate and peer graded course threads have high attention decline rate.

[25] Reports that the students who learnt with mobile applications showed a higher engagement with the lecture material and had a higher rate of completing the course. These days, universities have started including MOOCs along with their curriculum and library services. Institutes are making students get enrolled in MOOCs to earn that course credits as a part of their curriculum. [42] States that academic librarians can integrate MOOCs with their curriculum and library services.

## B. Limitations

Despite many advantages of MOOCs, there are limitations as well. Some of which are discussed below.

### 1) Role of Instructors

As in our study shown in fig. 5 we found the role of instructors does also play an important role in making an online course understandable by the students. Open Educational Resources have the lowest level of involvement of instructors whereas Instructor-led online courses have the highest level of instructor involvement. MOOCs have involvement of instructors between Open Educational Resources and Instructor-led online courses (fig. 6). Despite a great level of involvement, MOOCs show the neutral effects of instructor interaction with the students. This is described in [2]. The study in [2] makes an analysis of whether inclusion of an instructor actually has an impact on overall course completion rate, in learning

outcomes, acquisition rate and overall satisfaction of the students. For this study, they have divided the

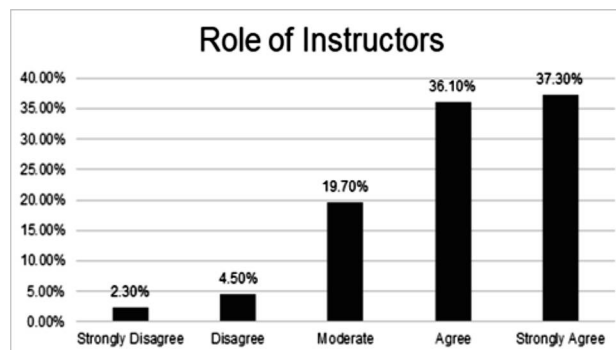


**Fig. 5 : Role of instructors in MOOCs learning**  
students into 2 groups:-

Group A: - It is a Control group. It has no interaction with the course instructors.

Group B: - It is an Intervention group. It has the active involvement of the course instructor.

The results revealed that there was no difference between number of students participating in forums, lectures and quizzes of both the groups. Number of Quiz badge earners was approximately equal of both the groups but the number of forum and project badge recipients of Group A is less than that of Group B.

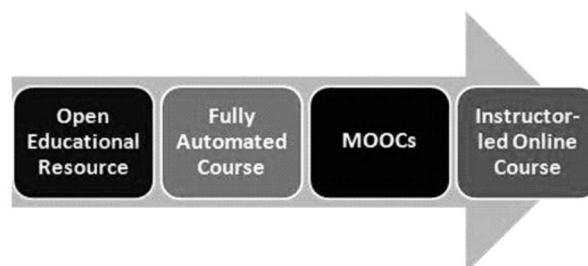


**Fig. 6 : Level of instructor involvement during an online course**

### 2) Student Engagement / Participation

[11] States that student engagement cannot be measured truly and also it can't track that if the downloaded videos are watched offline or not. In [20], it is being reported by instructors that discussion forums are the most useful information source but it is a fact that very few students registered to MOOCs are active on forums. [15] has the limitations as the decline rate factor does not consider the discussion timelines, i.e. whether the decline is continuous with time or is there some irregularity in it during

weekends, semester breaks, near semester exams, etc. It is suggested that the thread classification needs to be taken into account the teacher initiated topics and student initiated doubt-clarification topics to mark the relevance of the thread.

### 3) Classroom Teaching vs Online Teaching

Another study is conducted on a course on “An Introduction to Recommender Systems” [23]. This course was offered in two formats – one was the online course that was offered on Coursera and other was offered as a 3-credit graduate level course at the University of Minnesota. The university course was offered in form of a flipped classroom where students were asked to register for the same course offered on Coursera and take the lectures from there only using online materials provided and complete assignments and projects that were asked in online course. The study revealed that the university students were getting an advantage as there was the presence of instructors and teaching assistants and they were providing extra help to students facing problems in understanding some concepts and completing their assignments and projects. So, this study reveals that classroom teaching is better than MOOCs teaching and the same findings we got in our survey as shown in fig. 7.

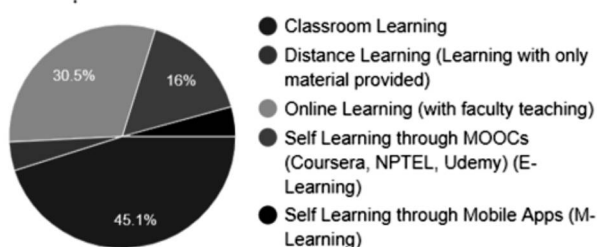


**Fig. 7 : Students inference on type of education they prefer**

As classroom teaching is found more effective as compared to distant learning, [26] describes the retention rate of students is low in distance learning courses i.e. only a small number of students complete their courses successfully. [18, 29] Illustrate the factors like usefulness, satisfaction, reputation and openness are responsible for low retention rate in MOOCs.

#### 1) Effect of Hints / Chat Rooms

In there is a study of hint systems and results show that hints negatively impact student performance.

Asynchronous mechanism of learning is combined with synchronous mechanism in by making use of chat rooms. Students in this study were divided into 3 groups: - non-chat, chat tab and embedded chat conditions. Results concluded that there were no significant differences between grades of students in chat condition and non-chat conditions and equal number of students posted to the discussion forums in these conditions and no significant difference in the result was seen. So, this study concluded that chat rooms are not useful. In our survey as shown in fig. 8, we found that many students are agreeing that hints impact their learning in other ways such as it makes them dependent on hints which makes them less confident for real problem statements.

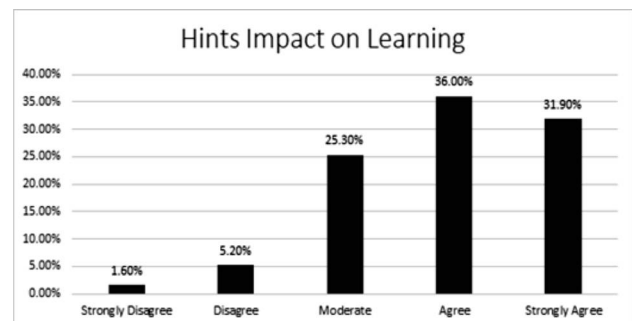


**Fig. 8 : Hints impact on students confidence level in learning**

At the end we are summing up this section by providing a summary in table 1 of advantages and limitations of MOOCs based learning.

**Table 1 : Summary of Advantages and Limitations Of E-learning**

| Advantages                                                                     | Limitations                                                                                                            |
|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Students can discuss everything with anyone at any time.                       | Students can drop the courses if they don't acquire the prerequisite skills.                                           |
| They help weak students (backward sections) to learn things at their own pace. | Passive mode presence of an instructor doesn't create an effective communication channel between educator and learner. |
| Most MOOCs are free.                                                           | It is the sole responsibility of students to carry the course successfully.                                            |
| Their interface is user friendly and interactive.                              | Sometimes, communication becomes a problem.                                                                            |

#### 4. Advantages and Limitations of M-learning

##### A. Advantages

There are several advantages of M-Learning. Some of them are discussed below.

##### 1) Effect in Rural Areas

Mobile learning techniques make education more accessible in rural areas of developing countries. The objective of [12], [13] and [14] is to explore the scope of mobile learning in developing regions of the world, like India. The authors of [13] have designed learning games using a format of receptive-activation cycles. In receptive phase, a set of words were introduced by playing their audio pronunciations and showing graphics of their meanings on the screen, followed by a practice phase where learners spent their time in practicing with items as long as they want, followed by an activation phase where a randomly selected word from the set of introduced words is displayed or read aloud and the player has to guess its corresponding meaning. [14] Presents the PACE framework (Pattern-Activity- Curriculum-Exercise) that helps to teach English language to rural India. The results show that use of mobile phones to teach rural children was a great success as some degree of academic learning occurred and also PACE framework yielded positive learning outcomes.

##### 2) Live Video Streaming

As the population is gradually increasing, there is a need to educate more people and establishment of new institutes is not feasible to give admissions to everyone. So, a need to provide distance education to a large population is felt. The research of [16] was conducted on two large classes containing about 1000 students each of Computer Science and English courses. Mobile Live Video Streaming System (MLVSS) is developed in [16] that streams live video lectures to mobile phones of users. Three views of lectures were delivered - (a) slide view (b) slide and teacher view (c) teacher view.

There are three users of MLVSS –

1) Teachers who deliver slides and hand written information in high quality, receive feedback from students and are able to see students screen watching lectures at that time.

2) Students who can see lecture timetable i.e. lectures currently available and select one of them, zoom in and zoom out the lecture content, give feedback to teachers regarding their teaching speed, handwriting, transmission quality etc., ask questions and get answers to most questions immediately.

3) Administrators who maintain and take care of proper transmission of content.

The architecture has two subsystems: Mobile Phone Broadcasting System, which broadcasts content to mobile phones and the other, is Classroom Management System, which is responsible for students' interactions with lectures. Mobile Phone Broadcasting System is composed of three components- Classroom Recorders which encode data; Broadcasting servers which transmits data to mobile phones and Client Viewer which enables students' to view videos. Classroom Management System is composed of four components which are defined as follows-

1) Curriculum Schedule Management System- It displays currently available lectures to students and allows them to select one. It also helps to avoid downloading of duplicate lectures.

2) Client Screen Monitoring System – Every 30 seconds, students' screen is captured and shown to the teacher so that teacher can have control over his students. Students can enable/disable this feature because of privacy reasons.

3) Polling System – Students can give feedback to teachers regarding teaching speed, handwriting and voice.

4) SMS Interaction System – Students ask questions using SMS service (text messaging) and important questions get answered immediately.

This work evaluates that in both the courses students are highly satisfied with the system.

##### 3) Role of Social Network Sites

As per our survey on mobile device usage shown in fig. 9, we found that people use it mostly for surfing social networking sites. Hence social network sites (SNS) can play a major role as a learning medium in mobile learning communities. [1] Aims to find out the social interactions' impact on the mobile learning

community, which is integrated by mobile equipment. This study reveals that there is a great impact of social interactions on the mobile learning community. Another study [43] has used a social network platform named Facebook for learning and teaching purposes. The results were highly satisfactory.

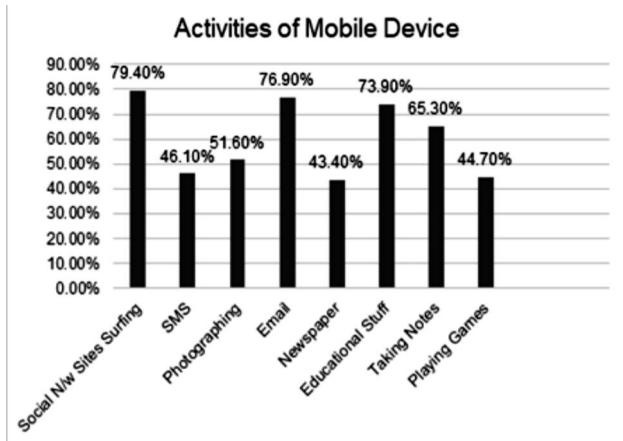


Fig. 9: Students interest on mobile device usage

#### 4) Interaction, Team Formation and Training

In Mobile learning, users share their experiences and exchange their ideas while working on assignments together. Due to the constraints, face to face conversations are difficult among team members and so are their understandings. Team formations become crucial in such a scenario based on each learner's strengths and weaknesses. The major task is to mark each learner properly based on their individual contributions. Suggests a method to provide Teamwork as a Service (TaaS) with the facility to provide a platform that can be shared between students and teachers. Kolb Learning Style has been used in this model by basically mapping the 4 styles of learning i.e. accommodating, assimilating, converging and diverging to their respective roles.

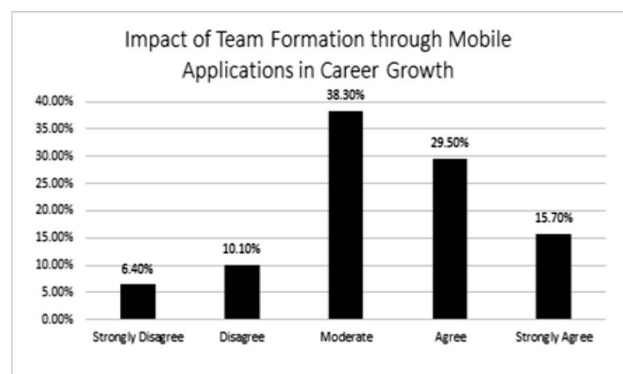


Fig. 9: Students interest on mobile device usage

This facility of TAAS helps in building team relations and thus it leads to team work in assignments and projects. In our survey as shown in fig. 10, many respondents also agreed that this team formation also helps them in their career growth.

In [28], three types of learning systems are compared - Mobile learning, Map based learning and Game based learning. Game based system was more difficult to use than the other two systems as it did not allow the participants to physically visit the rooms and interact with the real building environment. The map based system did not support the way to find a room and also did not include interactive features, whereas these features were supported by mobile based systems. This study results that participants with mobile based systems performed better than other two systems. A recent study described in [41], reveals that Mobile Instant Messaging (MIM) which is a massive communication phenomenon is an extension to mobile learning platforms.

Another study [30] reveals that mobile learning in teacher training is a great success. In this study, trainees and the supervisors discuss and share their ideas on teaching methodologies through SMS and digital pictures, which turn out to be great success. [38, 39, 40] reveal that mobile learning platforms are quite useful for higher educational universities or institutions to support teaching and learning.

#### 5) Flow Experience

[28] Aims to analyze the concept of flow experience to the process of mobile learning. Flow experience can be defined as:-

Whether the user is engaged or focused on material.

- Whether the user is curious about the material.
- Whether the user is getting distracted away from material.

Fig. 11 explains that if a person is having a higher skill level and the activities assigned to him are not challenging, then the person feels boredom while doing that activity and thus may disengage from that activity. Also, if the person is assigned an activity/task which has higher challenges than his skills, this may also lead to disengagement from that activity.

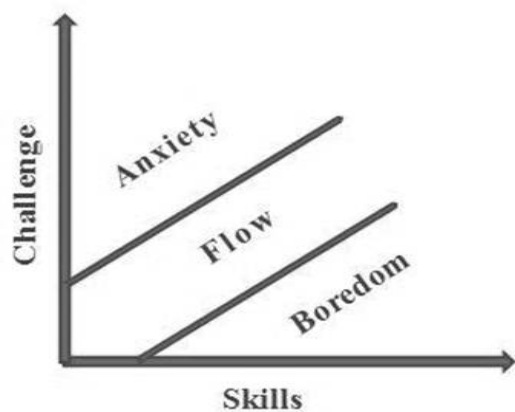


**Fig. 11: Flow experience**

## B. Applications

Based on our survey as shown in fig. 12, we analyzed that learners feel a lot of benefits of mobile applications based learning. The major benefits came in terms of cost and time effectiveness and enhanced learning experience.

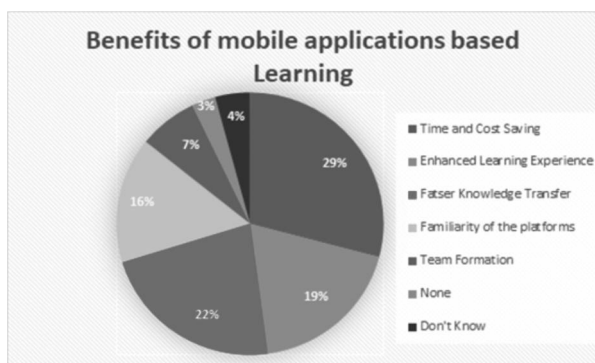


**Fig. 12 :Benefits of mobile applications based learning**

There are several applications of M-Learning. Some of them are discussed below.

### 1) Adapted Learning Content

An Adaptive neuro-fuzzy inference system (ANFIS) is proposed in [31] that provides adapted learning content to mobile learners. A mobile learning reasoning engine is presented, which provides a suitable learning content format for a mobile learning application using ANFIS system.

Mobile2Learn framework is presented in [32], which helps to access and reuse Mobile Assisted Language Learning (MALL) resources. The participants of this framework are English language teachers who search and reuse these resources for teaching and also share them with foreign language

teachers. Two of the most important tools of this framework are Mobile2Learn Web Repository and Mobile2Learn MALL Courses Delivery tool which provide the knowledge to mobile learners.

### 2) Clickers

Clickers also serve a purpose of m-learning. Clickers are handheld electronic devices which provide voting functionality for multiple choice type questions. Popularly, they are being used in quiz shows for audience polling. They are also used in classrooms for quizzes and feedback. [33], [34], [35], [36], [37] explore various modifications to these traditional devices and are similar in their end result of replacing the clickers but differ widely in the way that is achieved.

### 3) Mbelick

Mbelick [33] is designed for presenting in-class quizzes. Responses are sent either by using the phone's built-in web browser, or by using a dedicated smartphone application, or by SMS text message, and subsequent personalized feedback is sent on the students' phone itself. Instructors provide lecture based questions and feedback is textual. Smartphone users have to login to the relevant numbered session or send SMS.

### 4) Votapedia

[34] Talks about a mobile phone based Audience Response system, called Votapedia. It allows users to vote through web, SMS or vote by dialing, which despite 'engaged tune' flaw is a novel concept. Each survey type has multiple options, a maximum survey time, number of allowed responses per voter, whether web based voting is allowed and how many responses per voter are allowed.

### 5) Classroom Response System

[35] Makes use of multi-functionality smartphones to extrapolate the benefits of Clickers in traditional multiple choice questions to illustrative and short answer type questions. The rich Classroom Response System (CRS) has two stages: student response and instructor feedback. Two tests are used- Clicker Test and Concept Retention Test in rich versus traditional setting, where the former shows better results for rich type questions but is ambiguous due to small sample size for the latter case. Since the testing had not yet

been completed for instructor feedback, it is early to comment on the usefulness of that feature. However, server data can be analyzed and automatic feedback to individual students can be designed using the graphic feature of the smartphones.

#### 6) Quizit

[36] Presents the development of Android mobile devices named QuizIt. Native app is used over HTML5 as it is easier to use, is user friendly and has faster responses. The lecture application or the web environment are used to insert questions, delete existing questions, activate existing questions and see and delete the results. The student application is used to play the question with the choices one after the other. It does away with the need of displaying the questions and choices on a projector and instead displays them on the app itself.

#### 7) Pencast

Pencast [37] is a technological development which is used as an audio visual tool where a handwritten note is recorded in real time along with the instructor's vocal explanations. It is basically a digital pen with microphone and camera, and the written file is saved as a PDF. Viewed along with the audio, it serves as pre-read before and after the class and is meant to enhance concept retention. It can be used in sync with clickers or mobile clickers to improve the understanding and retention of students.

#### C. Limitations

Besides these advantages and great applications, there are some limitations of Mobile Learning. In our survey as shown in fig. 13, we found that in mobile learning the major barrier is to face the distractions available in devices for users in the form of applications. Other challenges include internet service availability, and hardware restrictions.

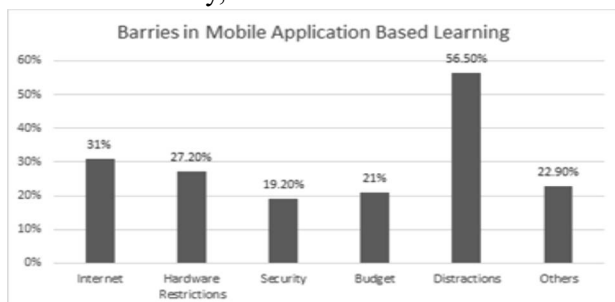


Fig. 13: Barriers in Mobile Application based learning

**Table 2 : Summary of Advantages and Limitations of Mobile Learning**

| Advantages                                                                         | Limitations                                                                                                |
|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| It costs less to students.                                                         | Students who cannot afford their own devices are left out of the courses.                                  |
| It involves less risk for the institution.                                         | Students can make misuse of mobile devices instead of learning.                                            |
| Students have a familiar device which is a Smartphone.                             | Incompatibility problems like network issues may occur.                                                    |
| Students can study well on their own devices rather than on institutions' devices. | Software compatibility issues like not upgrading to a new version, regular system crashes, etc. may occur. |

#### V. Discussion

We can see that MOOCs and mobile learning; both are the face of future education system. In such systems, instructors play a very important role as mentors. This can be analyzed by applying various machine learning algorithms such as Decision Tree, Naïve Bayes, Logistic Regression and Multi-Layer Perceptron (MLP) on the pilot data. The results of each algorithm are described in Table III.

**Table 3 : Results of various machine learning Algorithms applied on our dataset for the role of instructors**

| Method              | Accuracy (%age) | Precision | Recall | F Measure | MAE   |
|---------------------|-----------------|-----------|--------|-----------|-------|
| MLP                 | 69.13           | 0.800     | 0.818  | 0.809     | 0.215 |
| Naïve Bayes         | 72.37           | 0.796     | 0.901  | 0.845     | 0.234 |
| Logistic Regression | 72.89           | 0.781     | 0.931  | 0.849     | 0.235 |
| Decision Tree       | 73.80           | 0.764     | 0.951  | 0.847     | 0.252 |

Decision Trees perform the best among all having an accuracy of 73.8003% and Mean Absolute Error (MAE) of 0.2523.

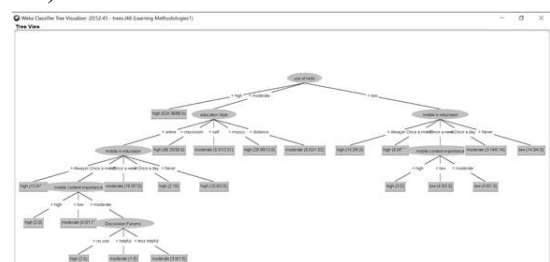


Fig. 14 : Decision tree for the role of instructors

Fig. 14 shows the decision tree taking leaf nodes as role of instructors. Role of instructors is classified as high, moderate and low. High role of instructors indicates that there will be high use of hints and no use of discussion forums.

## 6. Future Work

### A. MOOCs

The study in [15] focuses mainly on the sharp decline rate of interaction on most of the MOOCs with time and facilitates easy navigation of relevant information through overloaded discussion forums. This work can be applied to find the most read topic by an Ebook/kindle reader and revert them back with suitable further reading suggestions. It can also be used by users to find relevant feedback in e-commerce websites and by the company to find the gist of the feedback, classify and rank them accordingly. The work in [4] does not make progress to understand why the hint systems negatively impacted student performance. Future work needs to be done to improve the utility of feedback and discussion forums to learners. Hence more work needs to be done to suggest relevant individual topics and threads to the learners so that their activities get increased on discussion forums and they can utilize the benefit of the discussions to the maximum.

### B. Mobile learning

M-learning can be used to provide immediate knowledge to help individuals. It can be seen as the next wave in the education domain. As the speed of business and information overload is increasing, everyone requires information and knowledge just when they need it in their desired format and in the mobile platform of their choice. It can be applied to everything from product training to IT and organizational training. It is suggested that the Mobile Live Video Learning System (MLVSS) can be used to conduct live quiz contests among the learners so that they remain active throughout the session. The study in [12], [13] and [14] is carried only for rural people but it can be extended to reach the entire rural community. M-Learning can be used to provide practice questions, make connections with peers and instructors, and access knowledge [24].

Further suggestions come to Mobile learning applications like mbclick [33] can be used to conduct quick audience surveys. Further applications of

mbclick include deployment in sport grounds for the audience to answer polling questions such as which team is likely to win or who would be Man-of-the-match. Votapedia [34] can be used for rural settings where language options can be embedded in vote by dialing and combined with web voting for web sessions. In QuizIt [36] more features such as graphical questions and ratings could be used to make full use of android OS. Pencasts [37] can be proved as a replacement of chalks and markers used by academicians and the instant generated notes can be used as supplementary reads.

## 7. Conclusions

E-learning (MOOCs) and m-learning both are growing steadily as a means to provide distance education to people who cannot attend classes. Both MOOCs and m-learning technologies have various advantages and limitations which have been discussed thoroughly in the paper.

Some of the advantages of MOOCs include the contribution made by videos feature in making MOOCs a huge success as the learner can learn from the videos at his own pace. Other important features include automated evaluation by the system as well as combination of peer and automatic system, superposters who help in by posting detailed answers to questions and by asking good questions. Forums are the best social tool preferred for discussions. Some of the limitations of MOOCs are that instructors do not play an important role in the course. Chat Rooms and hint systems are not of much use. Age, gender, highest degree qualification, programming confidence, status as a professional, graduate or undergraduate student and English proficiency all had no impact on completion rate of the course.

Mobile learning has some advantages such as that it can be used for teaching rural people along with urban people. Mobile Live Video Learning System (MLVSS) provides live streamed video lectures to mobile phones of users, social network sites (SNS) can be maintained on mobile phones that help in learning. Learning Management Systems (LMS) provide a virtual platform to work together in assignments, ANFIS system delivers adapted learning content to mobile learners, Mobile2Learn framework helps to access and reuse Mobile Assisted Language Learning (MALL) resources. Clickers are also helpful for m-learning purposes.

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# Impact of the flipped classroom approach in engineering education: A course analysis

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**Abstract:** The main purpose of the paper is to present a course analysis on the use of the flipped classroom. The objective is to explore the advantages and challenges for students and instructors. The impact of flipped classroom learning is analyzed with a set of students in the classroom. Student perceptions of lecture based learning and flipped classroom is compared to explore and promote active learning methodologies. The challenges of implementing a flipped classroom were identified and addressed using a variety of student-related activities. Mobile app learning methods, scale-up classroom and effective laboratory courses were implemented for a set of students. The significance of the flipped classroom model is noted. It was found that it promotes a deeper, broader perspective on learning, improves critical thinking capabilities and team work skills needed for a successful engineering career.

**Keywords:** flipped classroom, scale-up classroom, active learning, learning outcomes

## 1. Introduction

These days, many universities are transforming lecture-based learning (LBL) methods of teaching to

flipped classroom (FC) teaching – a method of pedagogical aspect (Sohrabi & Iraj, 2016). The flipped classroom introduces a new solution to the challenges of traditional education. Hao (2016) have implemented this approach in higher education in different disciplines such as mathematics, social sciences, pharmacy and engineering. In lecture-based learning, interactivity is considered a tool for success. It is however, keenly noted that a lack of interactivity, a pedagogical approach, is missing in the traditional classroom. A brief study of Wang, Feng and Hsu (2017) revealed that only questioning and answering with the students is taking place in lecture-based learning.

The flipped classroom aims to address the many challenges of the traditional classroom approach. The present classroom scenario between instructor and student stops with question and answer. The objective of active learning is to enhance this using a smart education system. When using the flipped classroom, students are asked to perform group tasks, individual tasks and problem solving as a few of the best practices. A day before the class starts, course content materials in the form of online videos, slide presentations and open education resources (OER) are given to students. Students learn and utilize the online course materials. This differs from traditional learning in that instructors not only transfer knowledge through lecture notes. The flipped classroom involves active learning through problem solving as

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individuals and in groups. This increases the potential for student learning. Figure 1 compares different aspects of the learning environment, inside and outside of the classroom, for a flipped classroom and conventional mode.

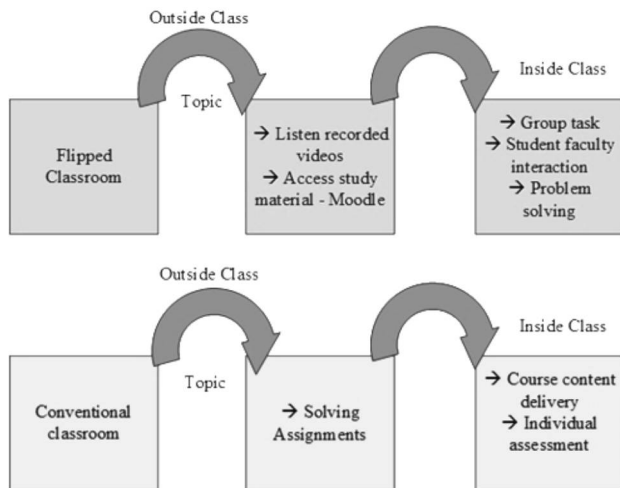


**Fig. 1: Different aspects of the learning environment**

A recent study focused on student perception and object learning outcomes and the impact created by the flipped classroom (Li et al., 2017). Maratou et al. (2016) and Jonassen (2000) also showed that the flipped classroom is a more flexible learning environment than lecture-based learning methods. There are however, a few limitations such as the design of course materials for better understanding of all students, not actively participating outside the classroom.

In recent years, research articles based on the flipped classroom approach have increased globally. Due to the increased use of the internet and information communication technology (ICT) the practice is followed in higher education, particularly in engineering education. There is a surge of new business models namely MOOCs (massive open online courses) – an emerging education system that does not require any tuition fees but rather an individual course fee that is affordable to students. This system results in a rethink of the way education is delivered.

To evolve, software engineering courses should be designed with a learner-centered learning environment to increase learning performance. To highlight this, Munitr et al., (2018) and Lai et al., (2016) stated that the study instruction of theoretical

methods and practical skills are required for software engineering courses and learner-centric and teacher-centric strategies should be characterized by participation, knowledge, interaction and thinking skills.

For this study, the LBL method and FC method is used infrequently in our college and there is limited analysis related to course methodology, best practices like mobile app learning and the remote laboratory. This FC approach was implemented during the Covid-19 pandemic situation for enhanced transfer of knowledge to the student community and the improvement of academic results.

## 2. Literature review

### 2.1 Implementation and procedure of the LBL method

Shi et al., (2018) have examined whiteboard-based instruction for college students. The LBL method is also known as the traditional class and in this case, it was used as the control group. The method was handled as follows. The instructor gives the lecture to the students in the class for 60 minutes using digital learning tools like slide presentation and keeps engaged. Students are idle to listen the class. Later, the handout materials are uploaded in moodle platform. Outside the class, they were asked to do the assignments. The results of the study have proved higher levels of academic self efficacy and student learning achievement is not affected. However, the main perspective of LBL is to transform knowledge to students in classroom with less interaction.

### 2.2 The Flipped classroom learning method

When using the FC method, the instructor is no longer a speaker, rather he facilitates individual and group tasks that promote active learning for the students. Opportunity is given to students to engage in new content through small group discussion to improve their skills. Different activities that can be used in the classroom are shown in Figure 2. Hwang (2014), mentioned that new learning modes will raise new pedagogic issues. Thus, new technologies and learning strategies are needed to support this method.

Shi et al., (2018) stated that as instructor and student contact in the classroom reviewed and reported that flipped model yields student learning outcomes in a positive manner. As an added advantage, Schlairet et al, (2014) defined a concept

that is linked to three theories as behaviourist, cognitivist, and constructivist for a nursing course. This creates impact in students learning outcomes such as achievement and attitude. This interactivity approach transforms students in a rich learning environment.

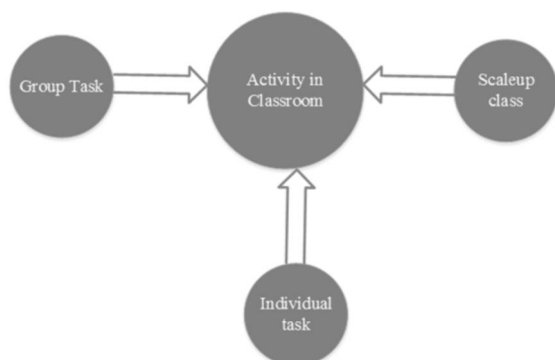


**Fig. 2: Activities performed in the flipped classroom**

Yelamarthi et al., 2016 and Kamerikar et al., 2020 have shown good results by applying this pedagogical approach in a first year course on digital circuits. The most significant contributions in pedagogy included a flexible learning environment. This allows the student to learn at their own pace if they miss the class. The strategy has been followed in pharmacy, medical and engineering with good results. Many institution had incorporated this pedagogical practice in the curriculum. Positive result of the individual student have made the class result much better than conventional method. In the flipped classroom method, the student can rewind, pause and learn at any time using present technology. Martinez – Rodrigo, (2017) report that students were prepared for class before class starts and project based learning (PBL) has improved the educational outcomes and student satisfaction in teaching the course. Individuals also reported that learning watching videos is easier than reading text books. They also discuss the four pillars of the flipped classroom method and its key components which is shown in Figure 3.

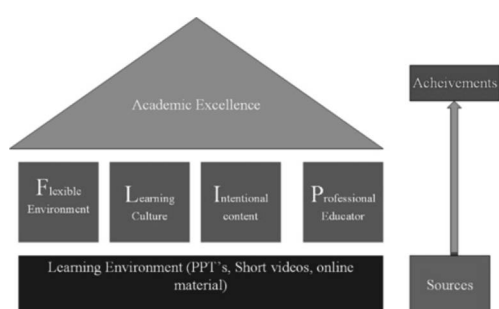


**Fig. 3: Key components of the flipped classroom**

## 2.4 Active learning methods

Many Indian universities have incorporated active learning methods into the curriculum. Programme outcome (PO), course outcome (CO) is a key role in engineering education. Outcome based education (OBE) is encouraged in engineering education and has proven success in helping institutions to measure learning outcomes. It also contributes in raising education standards to acquire accreditation such as the National Board of Accreditation (NBA). This significant initiative has increased the need to take necessary steps. Eichler, J. F., & Peeples, J. (2016) described how a student team of four engineering courses developed a video game approach for learning signal processing using project based learning. It also benefited students and gave an opportunity to upgrade the skills in the classroom. In the design part of course materials, the instructor has to pay more attention to create the high quality videos with rich content. Active learning methods have been shown to support students in creating new ideas and invoking knowledge. For the study purpose, Allais. S 2012, stated that learning outcomes are a major part of a curriculum and education policy reforms. The practice for different learning outcomes is shown in Table 1.

**Table 1: Learning outcome practice**

| Learning Outcomes     | A statement of what is to be achieved on successful completion of course.                                              |
|-----------------------|------------------------------------------------------------------------------------------------------------------------|
| Learning experiences  | The experienced candidates have to enable the knowledge and skills required for the learning outcomes to be addressed. |
| Assessment activities | Different task is given to candidate will engage with evidence they have achieved the learning outcomes.               |
| Assessment criteria   | A clear description of levels of achievement, and what performance is required at each level.                          |

## 2.4 Smart learning techniques

This section discusses smart learning techniques and integrating learning materials like the internet and data projector to support the FC method. These activities transform the learning environment into smart education. In group discussions, inner talents of students is identified in generating more ideas of the subject. Lai et al., 2016 approach have created significant interactivity and it is a key component in engineering education. Lin and Yen-Ting (2019) created web browsers supported by any devices for instructors and students for many learning activities (in and out of class) showing good results. Cummins et al., (2016) used in-video quizzes as an approach

which helped students to increase the interactivity of video content as formative assessment.

## 2.5 Mobile App learning methods

Recent developments in cloud technology have created new learning tools for material synthesis. This enhances the student skills in learning problem-based learning. Jou et al., (2016) created the Interactive Mobile Material Learning (IM2 Learn) app to facilitate student learning. Integration of mobile devices in present education environments focus on the classroom setting and its implementation. This creates an opportunity to guide students and help them effectively in acquiring knowledge. It serves as a complementary method to other forms of course delivery. Klimova, B. (2019) showed how their web app development had satisfied both student learning and study achievements. A need analysis evaluated SWOC (strength, weakness, opportunities, challenges) and was conducted at the beginning of the semester. Amongst the challenges of using mobile devices in the classroom, is that students face some distractions in the classroom. Asundi, S. (2019) described an alternate methodology of multi-tasking of the instructor in the role of facilitator. These learning methods had created innovative ideas for students and the teacher. The way of presenting the creative ideas in the mobile app to the student and the measurement of outcomes is a real challenge however. The objective would be technology enhanced learning methods for the students.

## 2.6 Activities using scale-up classroom

The scale-up classroom is designed to facilitate active learning environment in a team. Student-centred, active learning environments for undergraduate programs is a known acronym for the scale-up classroom. In the engineering discipline, it is used for collaborative problem solving in the undergraduate program. Students share their views and get stimulated with individual engagement. It involves students working on a group or individual task. The instructor interacts with students to create small discussion, questions, and debates keeps the class more interactive. Students are found to be active in these approaches. It can be identified by their communication skills, presentation skills and critical thinking in the form of projecting their views through cognitive thinking. The key activities performed in the scale-up classroom include brainstorming, problem-

solving and decision-making, role-play, simulations, games and making comparisons. Collaborative, web-based methods have been created for engineering education. The physical setup arrangement of a scale-up classroom is shown in Figure 4 with several round tables. The classroom is further equipped with a microphone, laptop and white board with marker. A small group is setup at each table with the facilities created. Heitink et al., (2016) proposed the use of online tools with an internet cable or wi-fi facility to share views on the particular topic. The instructor interacts with the group and individuals. The instant stimulated thinking can be represented online through excel, power point and graphs with pictorial representation. Projector screens in larger rooms allow viewing from anywhere in the room. Innovative ideas can be shared within the group and represented in their own way. This is a part of learning methods that facilitates the student community in improving their knowledge transfer in a set of group. The student has the ability to showcase their thoughts in their own representation through the aid of technology.

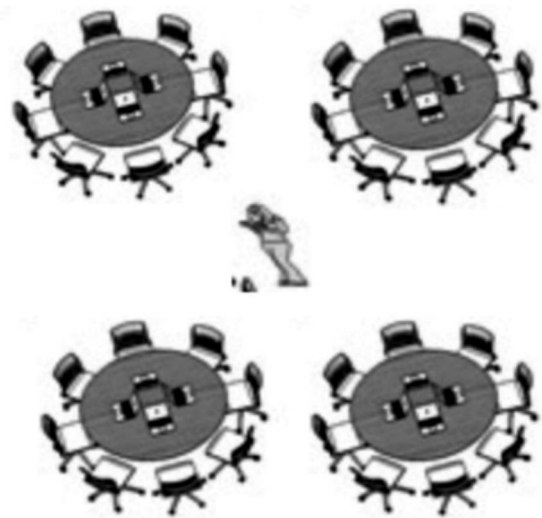


**Fig. 4 : Scale-up room arrangement**

## 2.7 Effective Laboratory Courses

Some theoretical courses need to include practical examples so that students appreciate and are involved in various hands-on activities. The main objectives of learning laboratory courses includes team work, motivation, object learning and networking. Other benefits include, inquiry-based learning. Borrego, M et al., (2009) often use conceptual knowledge transfer to students, integrating information text to experimentation quality. However, many courses

remain unchanged with the exercise and the same data or reports used every year. Recently, laboratory courses have been reduced due to increased student numbers and teacher funding resource constraints. Sensor modelling and simulation lab, electrical machines lab, virtual electric drives lab can give exposure to students in laboratory courses. Kavitha, D., & Anitha, D (2018) discuss a laboratory using remote desktop and online workbench for electrical experiments for engineering students and certain virtual remote laboratories in a defined manner.

## 2.8 Strategy of student Evaluation

When using a flipped classroom method, the scope of student evaluation (or assessment) is wider and the scope of examination is narrow. Qualitative progress and behavioural changes are tested in evaluation. In examination, only qualitative progress is explored. Assessment and evaluation are an integral part of engineering curriculum. Different forms and their benefits are included in Table 2. In order to evaluate the technical skills of students, multiple choice question (MCQ) type is used to measure the higher level mental process and a wide variety of learning outcomes. A broad range of topics can effectively be test the breadth of a student's knowledge. Students rate the level of confidence they have in their answer and that is the score. Regular test of MCQ has the good working knowledge. Student mentality is assessed with alternate type quizzes.

**Table 2: Different assessments and benefits**

| Assessment methods              | Benefits                                                                                                               |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Formative assessment            | Student modifying instructional objectives and correcting further learning in feedback loop                            |
| Summative assessment            | It measures instructional objectives. It results in mark or grade awarding final cumulative grade point average (CGPA) |
| Criterion referenced assessment | It measures student higher grade achievement learning outcome of course is achieved.                                   |
| Norm referenced assessment      | Individual student assessment is compared with his/her classmates on an assignment task.                               |

## 3. Experimental Procedure

This section describes the methodology of the study and demographic data of participants.

### 3.1 Study methodology

This study focuses on evaluating two approaches-lecture based and flipped classroom mode in a four-year, engineering degree college at Madanapalle Institute of Technology & Science, Madanapalle, Andhra Pradesh. For the academic year (2018-19) learning methodologies like lecture-based and flipped classroom mode were used. For one semester, our college flipped three fundamental courses for three main engineering disciplines for electrical & electronics engineering, electronics and communication engineering and computer science engineering. All of these courses were at the second year level. Details of the engineering courses and student demographics is tabulated in Table 3.

**Table 3: Engineering discipline, courses and student size**

| Number | Engineering discipline                    | Fundamental courses                | Class size              |
|--------|-------------------------------------------|------------------------------------|-------------------------|
| 1.     | Electrical and Electronics Engineering    | DC Machines & Transformer          | 53 (male:45, female:8)  |
| 2.     | Electronics and Communication Engineering | Introduction to electronics        | 60 (male:50, female:10) |
| 3.     | Computer science engineering              | Introduction to python programming | 60 (male:45, female:15) |

The framework of all learning methods in flipped classroom was used. Interactive group learning activities were used inside the classroom and direct computer-based individual instruction was used outside the classroom. A mobile app and scale-up classroom were also used to improve active learning. In this research, student performance is analysed both in flipped mode and LBL mode through student assessments and continuous internal assessments (CIA).

## 4. Results

Table 4 shows the average of continuous internal assessment (CIA) and standard deviation (SD) of two engineering discipline. For the electrical & electronics engineering, the success of quiz does not reflect the student gaining knowledge on topic area. The CIA-1 equals to quiz 1-4 and CIA-2 equals to Quiz 5-8. The scores show that the first CIA-1 of flipped model shows less result than LBL method of

teaching. It depicts initially student felt difficult in flipped model later in CIA-2 the student performed well.

The (Avg: 85, SD: 5.5)  $t(20) = -3.56$ ,  $P = .03$ . For computer science engineering in the CIA-1 flipped model student performance is quite higher than the LBL method. The SD is 4.7 in flipped and 4.4 in LBL

method. Self-efficacy and the motivation for self-learning are necessary in engineering careers. Based on the above flipped classroom practice, students & faculty have shared their experiences and views and it is tabulated in the Table 5. This data was collected during training and placement activity from each student and by conducting various assessments like social, psychological and academic.

**Table 4: Quiz averages and standard deviation of Flipped and LBL method**

| Continuous Internal Assessments (CIA) |      | Electrical & Electronics Engineering (Flipped) |      | Electrical & Electronics Engineering (LBL) |      | Computer science engineering (Flipped) |      | Computer science engineering (LBL) |  |
|---------------------------------------|------|------------------------------------------------|------|--------------------------------------------|------|----------------------------------------|------|------------------------------------|--|
|                                       | Avg. | SD                                             | Avg. | SD                                         | Avg. | SD                                     | Avg. | SD                                 |  |
| CIA -1: Quiz:1-4                      | 76   | 4.3                                            | 81   | 4.8                                        | 80   | 4.7                                    | 79   | 4.4                                |  |
| CIA -2 : Quiz:5-8                     | 85   | 5.5                                            | 80   | 4.4                                        | 82   | 5.3                                    | 76   | 4.5                                |  |

Sample undergraduate courses is taken for the study that includes DC machines & Transformer, Introduction to electronics and Introduction to Python Programming The core and programming courses have taken for consideration. Class size of 60 have taken different courses. According to student choice they have shown interest in LBL and FC model in learning. The end result analysis says many students of below average students have shown interest and participated in flipped classroom. The average students have shown partial interest. In Figure 5 the trend analysis shows that learning activities in classroom is classified into traditional learning and flipped learning methods. Most significant courses have been taken to measure the practices of students and their participant in the classroom. In deep analysis, below average, and above average students have been classified in a class.

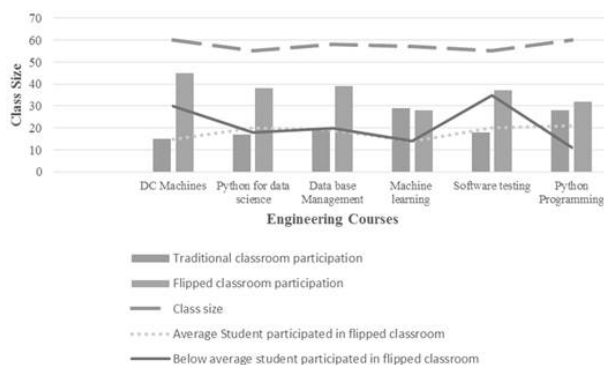


**Fig. 5: Analysis of traditional classroom learning and flipped classroom learning**

**Table 5: Listed benefits of Flipped classroom environment**

| S.No | Social benefits                                                                                                                                 | Psychological benefits                                       | Academic benefits                                 |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|---------------------------------------------------|
| 1.   | Establishes a positive environment for modelling and practising cooperation.                                                                    | Self-esteem through student centric.                         | Academic results are improved                     |
| 2.   |                                                                                                                                                 | Creates positive attitudes among students towards instructor | Active participant of student in learning process |
| 3.   | Builds positive heterogeneous relationships and promotes diverse understanding amongst students and staff.<br><br>Develops learning communities |                                                              | Inter personal skill development                  |

In many courses, students show interest in flipped classroom method rather than traditional method. The most traditional electrical engineering courses like DC machines have been student's most interest in flipped classroom learning. However, in few programming courses it shows student participants is equal. Below average students shows more variations in the learning methods. However, programming courses would be the choice for students in flipped classroom method. The student uses mobile

application to contact colleagues through facebook, twitter, and SMS learning materials for their convenient.

#### 4. Conclusion

The main objective of this research were to determine student involvement through class and exam attendance and to measure (quantitative) student involved in flipped classroom experience. Although, there are many surveys, student performance and course instructor perceptions were compared to the same course offered in LBL method, with promising results. The learning practice is taken through information and communication technology (ICT) to the students. Overall outcome of the research is to provide literature by filling existing gaps in engineering education by providing FC approach. Implication shows that learners change the method of learning based on the selection of courses. The findings pertaining to student satisfaction have been influenced by design aspects of learning materials used in flipped classroom. This study investigated that although flipped classroom has given opportunity to save time for the instructors and to deliver the course content to the students. In addition to that, use of mobile app create enjoyment in learning and commented that size of the phone and text bigger is more convenient for reading.

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# New Normal Appropriate Learning Model: 2NAL Model during COVID-19 Pandemic for Undergraduates of Thai Educational Institutions

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**Abstract:** Due to the serious COVID-19 pandemic and the adjustment of educational management in Thailand that caused the change of learning model from old to new normal by online learning at home, the objectives of this research were to study and analyze the factors of new normal appropriate learning model: 2NAL model during COVID-19 pandemic for undergraduates of Thai educational institutions. The method of study was divided into 2 phases. First phase was to study the factors of new normal appropriate learning model for undergraduates discussed by 9 experts of public educational institutions. In-depth interview was used to ask the opinions about the factors of new normal appropriate learning model for Thai undergraduates. The questions were clearly structured and used for individual interview. For this phase, the data were analyzed by using qualitative data analysis. The second phase was to analyze the factors of new normal appropriate learning model for undergraduates discussed by 1,126 experts of all public educational institutions which provide undergraduate degree across Thailand. The research instrument was the questionnaire used to ask the opinions about the

factors of new normal appropriate learning model for undergraduates. The data were analyzed by using confirmatory factor analysis for this phase. New knowledge gained from the research was new normal appropriate learning model: 2NAL model which consisted of the factors as follows: 1) Content Literacy 2) Intelligence Literacy 3) Digital Literacy 4) Self Literacy 5) Collaborative Literacy and 6) Curiosity Literacy.

The results were very useful and important in developing new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai educational institutions in the next phase of the research. Also, it was used for learning management in the digital age with practical application.

**Keywords:** Learning model, New normal, COVID-19, Confirmatory factor analysis, Educational institutions

## 1. Introduction

Many countries around the world have been facing the severe COVID-19 pandemic including Thailand. This has affected learning management of Thai educational institutions to change the normal learning style to online learning style for students to study at home. However, there were problems in learning at home. The behaviour of the learners was not clearly seen by instructors and the ways of doing activities in the classroom were limited compared to normal

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classroom (Hoi et al., 2018). With this situation, the teaching style has been adjusted based on the context. From the reasons and problems mentioned above, the research had the idea to develop the new normal appropriate learning model during COVID-19 pandemic for undergraduates of educational institutions across Thailand. This was to encourage students to express their behaviour and participate in the activities organized by learning management through online channels appropriately and to achieve the learning goals with a successful learning management. This model was regarded as the new normal appropriate learning model based on the situation previously mentioned.

The model could be used for learning management in the digital age by using online media to provide the teaching and learning activities for the students to study at home and to develop expected level of their competency in terms of student-centered learning. Thus it was very challenging to develop the new normal appropriate learning model based on the context of the situation previously stated. Learning management must be provided through online professional learning networks to encourage the learners to develop the competency with their full potential (Doe, 2015). The learners must be able to learn by themselves and to seek new knowledge to develop continually based on the digital literacy under the supervision of instructors (Ellis et al., 2020).

In conclusion, although many countries have faced the severe COVID-19 pandemic, it was really necessary for the educational institutions to provide learning and teaching continually. The learning and teaching style must be changed based on the context of each country (Van Lancker et al., 2020). Thai educational institutions had to change the old learning style to online learning style or study at home and the instructors were the administrator of their own subjects. It was not easy because the instructors could not see the reaction of the learners clearly and thoroughly. Without the appropriate learning style, learning management could be failed (Hodges et al., 2020). Thus the appropriate learning style on the situation mentioned previously was regarded as the important key for the instructors to organized the learning activities and to make the students participate in the learning continuously and efficiently (Ilmiyah et al., 2020).

Compared to other research topics presented by such as Bao (2020); Burgess (2020); Ding et al.

(2018); Gillen et al. (2018); Hoi et al. (2018); Zhou et al. (2020), this research was different and remarkable by using the technique of mixed method - qualitative and quantitative. This research started by using qualitative method. In-depth interview was used for a group of experts to study the factors of new normal appropriate learning model for Thai undergraduates. The questions were clearly structured and used for individual interview. The data were collected and compiled from experts of public educational institutions by using the questionnaire again. For quantitative data analysis, confirmatory factor analysis was used to confirm the empirical data (quantitative data). This was to check it was in line with the qualitative data or not. Goodness of fit statistics was used as the standard to make different and remarkable to the research. The literature review showed that the research was relevant to the contexts of many countries such as Almanthari et al. (2020) from Indonesia, Bao (2020) from China or Crawford et al. (2020) who did the research of the responses of digital teaching in higher education from 20 countries across the world. The results from the research showed that the educational institutions didn't stop learning and teaching activities but they all adjusted the style of learning and teaching. Thus this research was remarkable because the learning style was developed by brainstorming with a group of experts of public educational institutions which provide undergraduate degree across Thailand and it was appropriate for the context of Thailand. The main objectives of the research were to study and analyze the factors of new normal appropriate learning model during COVID-19 pandemic for undergraduates of educational institutions across Thailand. The results of the research were very important and useful because they could be used to develop new normal appropriate learning model during COVID-19 pandemic for undergraduates of educational institutions across Thailand in the next phase of the research. It was also used for learning management in the digital age with practical application. Henceforth, to be short and concise, "2NAL model" will be used to stand for the name of the research.

## 2. Literature Review

The literature review related to the study to consider the factors of 2NAL model using to support the research model of the factors of 2NAL model were summarized as follows:

Content Literacy: CL means the skills in

organizing the subject content based on course description or the scope of the content arranged in order of difficulty. The width and depth of the content studied during COVID-19 pandemic are considered including the scope and the order of the content presented to the students at that time (Barnett, 2020); (Gess-Newsome et al., 2019).

**Intelligence Literacy:** IL means the skill and ability of the instructors and students in leaning management and appropriately adjusting to the problems during COVID-19 pandemic. It is also the ability to do learning activities purposefully with social impact, including the ability of logical thinking, adapting efficiently to circumstances and society (Barnett, 2020); (David et al., 2020).

**Digital Literacy:** DL means the skill in understanding and using digital literacy. It is also the skill in using tools, materials, and digital literacy at the present such as computer, smart-phone, tablet, computer program and online media for the best interests in communicating, operating and co-working. Moreover, this skill can be used to develop the learning and teaching process to be up-to-date and efficient by covering 4 dimensions of ability which are Use, Understand, Create and Access digital literacy efficiently (Alvermann et al., 2019); (Suwanrojet et al., 2019); (Abdullaha et al., 2020).

**Self Learning Literacy:** SLL means the learning process skill that the students initiate their self-learning based on their interests, needs and skills. The students have their goals, are able to seek the learning resources, choose the learning methods and have self-assessment for learning progress. The students can choose to do by themselves or work together with others. This is the learning based on curiosity. The students will plan their learning by themselves (Artetxe et al., 2018); (Muthupoltotage et al., 2018).

**Collaborative Literacy:** CL means the learning through working group. The students will be divided into small groups with 3-6 members. Each member has different ability. They help each other in learning to reach the group's goal. They work and share responsibility. They accept each member's role and exchange the knowledge and experience between the members both in the classroom and on internet (Moreno-Guerrero et al., 2020); (Spruellet al., 2020).

**Curiosity Literacy:** CL means curiosity skill or a strong desire to know or learn something based on the

content of the subject and course description. This skill is from doing the activities by searching the additional information from different sources or experimenting in order to get the knowledge of the learners and discussing in the classroom by using the ability of the instructor through learning management or teaching by embedding with the learners (Jake, 2020); (Markham, 2020).

From the literature review related to the study mentioned above, the research acquired the research model factors of new normal appropriate learning model. Then the acquired knowledge was improved to be 2NAL model.

### 3. Method

#### Phase 1 The Study of 2NAL model Factors

##### Step 1.1 The study of factors for 2NAL model factors

Source was the literature review related to 2NAL model factors synthesized from the ideas of the academicians as follows: Abdullaha et al. (2020); Alvermann et al. (2019); Artetxe et al. (2018); Barnett (2020); David et al. (2020); Gess-Newsome et al. (2019); Jake (2020); Markham (2020); Moreno-Guerrero et al. (2020); Muthupoltotage et al. (2018); Spruell et al. (2020); Suwanroj et al. (2019). The literature review mentioned above was in 2018-2020 and used as the guideline to get the model factors. There were 12 topics selected and summarized from the contents of literature review. The main factors at least 2 of 3 were selected and synthesized based on the ideas of selecting and searching from the content of information in order to get the details of 2NAL model factors.

Research Instrument was qualitative data record which was synthesized from the documents. The steps in designing and checking the quality of the research instrument were as follows: first, the factors of 2NAL model were grouped to acquire the conceptual frame which consisted of 6 factors (as mentioned in literature review). Next, the data and details of 2NAL model factors were used as the guideline and used to design the qualitative data record. The documents which were the frequency record file of the factor list with the context details were studied by indicating the delimitation and issues for document analysis. Then, the qualitative data record was designed and presented to 5 experts to consider, develop and approve, respectively.

**Data Collection and Compilation** The data were collected and compiled from the document during 1-15 February 2020.

**Data Analysis** The qualitative data acquired from the qualitative data record synthesized from the documents and related research were analyzed by using content and frequency analysis. The research designed the table to summarize the contents. The frequency from the related ideas previously mentioned was checked. The details of 2NAL model based on the ideas were summarized and the frequency of the data was checked. To evaluate the analysis and synthesis, the ideas of Lin et al. (2019); Suwanroj et al. (2019); about the criterion in choosing the frequency at 50% were used to consider and determine the draft version of 2NAL model to use as the factors of 2NAL model in the next phase of the research.

**Step 1.2 In-depth interviews for asking the opinion about 2NAL model factors**

Source was the group of 9 experts who are from the public and private educational institutions and have expertise in developing learning model with at least 10 years of experience. Purposive sampling was used to select these 9 experts to be the key informants of the research.

Research Instrument was the in- depth interview questions to ask the opinions about the factors of 2NAL model which was appropriate for the new normal for Thai undergraduates. The questions were clearly structured and used for individual interview. Qualitative analysis was used to analyze the data covering 6 factors to find the list of observed variables. The content validity of in- depth interview questions was checked by the group of 5 experts before using in collecting and compiling. After obtaining the observed variables, the group of experts considered to confirm the details of 2NAL model factors which covered 6 subordinate factors. After the confirmation of the experts, the research obtained 18 observed variables which were used to design the questionnaire asking for the opinion about 2NAL model factors which was appropriate for the new normal for Thai undergraduates.

**Data Collection and Compilation** The data were collected during 1-10 March 2020 from 9 experts or 100% of the specified group of experts.

**Data Analysis** The statistics used for descriptive analysis were frequency and percentage. The criterion used to accept, consider and confirm the details of 2NAL model factors was the percentage up to 50% (Suwanroj et al., 2019).

**Phase 2 Confirmatory factor analysis of 2NAL model**

Population was the group of 2,929 experts who have knowledge and teaching experience not lower than 10 years in the public educational institutions across the country (Suwanroj et al., 2019).

Sample was a group of experts who have knowledge and teaching experience not lower than 10 years in the public educational institutions across the country. For sample size determination, the research used the concept presented by Suwanroj et al. (2019); Keith et al. (2018) which said that the way to determine the sample size depending on the amount of the factors that the research wants to analyze. The proportion of the sample must be 10 units for 1 variable and the sample needs 100 people at least. This research had 18 observed variables therefore the minimum of the sample size should not be less than 180 people. However, for the correctness and accuracy based on the statistical principle, the research used multi-stage sampling to determine the details of the sample to 1,126 people. This step followed all conditions for sample size determination as previously mentioned.

Research Instrument was the questionnaire to ask the opinion about the factors of new normal appropriate learning model for undergraduates. The questionnaire used 5 levels of rating scale. The content validity and the reliability for scale of the research instrument were 0.97 - 0.99. The content validity and the reliability for factor were 0.96 - 0.99. Second order confirmatory factor analysis was used for data analysis. To test the reliability, the research tried out the instrument with 100 experts who were not the same group of the sample. However, these 100 experts have knowledge and experience in teaching not lower than 10 years and work for the public educational institutions of Thailand as well. Cronbach's Alpha Coefficient was used to test the quality of the research instrument for the reliability aspect. From the test, the reliability of the research instrument designed for knowledge aspect was between 0.97 – 0.99. The reliability of the research instrument designed for all aspects was 0.99. This showed that the research instrument had an appropriate level of quality to collect the data.

**Data Collection and Compilation** By mailing a letter of permission and QR code of an online questionnaire to the sample group, the data were collected by scanning the QR code to answer the questionnaire. There were 1,126 responses sent back from the sample group or 100% of the specified experts. The data were collected and compiled during 1-30 April 2020.

**Data Analysis** The second order confirmatory factor analysis was used to analyze 2NAL model by using IBM SPSS Statistics 14.0 for Windows and LISREL 8.72. To analyze the factors which the research created the measurement model based on the literature review previously mentioned, it was needed to use the statistical methods to prove the correctness of the measurement model. At present confirmatory factor analysis is still very popular because of its high level of construct validity. Moreover, it can be used to create the new knowledge for the research correctly Suwanroj et al. (2019); Keith et al. (2018).

#### 4. Results

##### Part 1. Results of the Study and Analysis of Factors of 2NAL Model Learning Style

From the results of studying the related literature and the in-depth interview discussed by the experts to consider and analyze the factors of 2NAL learning style, the research acquired the conceptual framework of 2NAL model factors. After considering 2NAL model factors, the conclusion showed that the details and style of the factors consisted of 6 subordinate factors as shown in the figure 1 and there were 18 observed variables with the research symbols as shown in the table 1

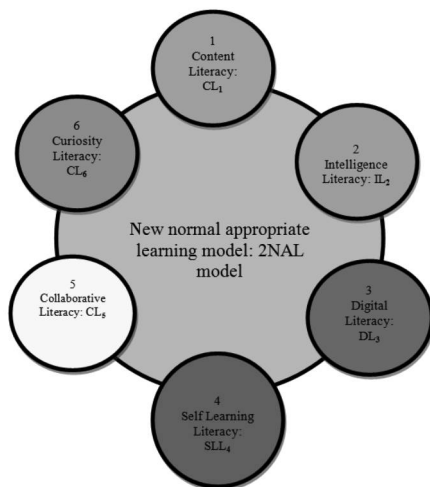


**Fig. 1: Style of New normal appropriate learning model: 2NAL model**

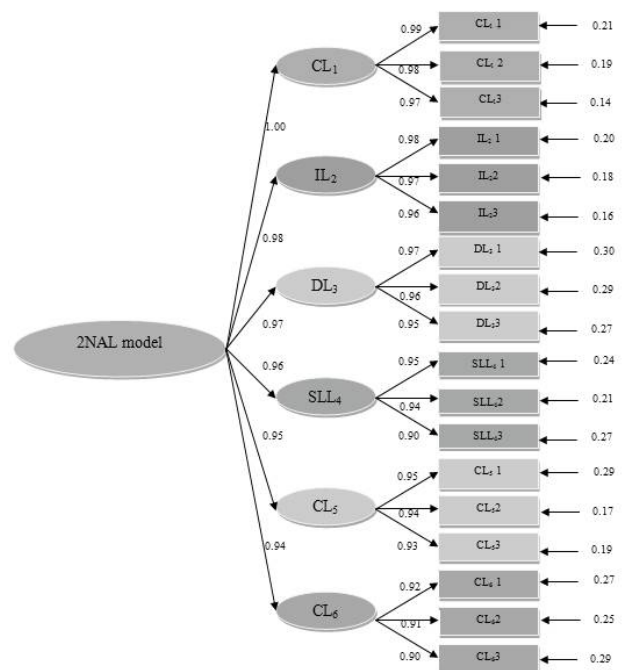
**Table 1 : Details of style, observed variables and symbols of 2NAL model**

| Factor                | Symbol          | List of observed variables                                                                                                                                                                       | Symbol            |
|-----------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| Content Literacy      | CL <sub>1</sub> | 1. Learning style had clear contents of the subject and was easy to learn by arranging the contents in order of difficulty.                                                                      | CL <sub>1</sub> 1 |
|                       |                 | 2. Learning style consisted of different activities such as learning from work sheet or skill sheet applied from the contents of the subject. The contents were arranged in order of difficulty. | CL <sub>1</sub> 2 |
|                       |                 | 3. Learning style consisted of different activities and media platforms. The contents were interesting and accurate.                                                                             | CL <sub>1</sub> 3 |
| Intelligence Literacy | IL <sub>2</sub> | 1. Learning style constructed responses and exchanges in different issues.                                                                                                                       | IL <sub>2</sub> 1 |
|                       |                 | 2. Learning style had clearly goal setting during learning management in order to create intelligence literacy.                                                                                  | IL <sub>2</sub> 2 |
|                       |                 | 3. Learning style stimulated intellectual thoughts rationally and efficiently.                                                                                                                   | IL <sub>2</sub> 3 |
| Digital Literacy      | DL <sub>3</sub> | 1. Learning style encouraged the learners to use digital media for learning management.                                                                                                          | DL <sub>3</sub> 1 |
|                       |                 | 2. Learning style used online channels and tools to support learning management.                                                                                                                 | DL <sub>3</sub> 2 |
|                       |                 | 3. Learning style helped the learners improve their digital competency both directly and indirectly.                                                                                             | DL <sub>3</sub> 3 |

|                        |                  |                                                                                                                                                                                                                                                                                                  |                    |
|------------------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| Self Learning Literacy | SLL <sub>4</sub> | 1. Learning style encouraged the learners to build the skill of self-learning process initiated by themselves based on their interests.                                                                                                                                                          | SLL <sub>4</sub> 1 |
|                        |                  | 2. Learning style created the skills in seeking learning sources and choosing learning methods.                                                                                                                                                                                                  | SLL <sub>4</sub> 2 |
|                        |                  | 3. Learning style provided self-assessment for learning progress. The learners could choose to do by themselves. This was the learning based on curiosity. The learners planned their learning by themselves.                                                                                    | SLL <sub>4</sub> 3 |
| Collaborative Literacy | CL <sub>5</sub>  | 1. Learning style had an emphasis on working group. The learners were divided into small groups.                                                                                                                                                                                                 | CL <sub>5</sub> 1  |
|                        |                  | 2. Learning style had an emphasis on different abilities of each member. They helped each other to reach the group's goal. They worked and shared responsibility.                                                                                                                                | CL <sub>5</sub> 2  |
|                        |                  | 3. Learning style provided knowledge and experience exchanges between the members both in the classroom and on internet.                                                                                                                                                                         | CL <sub>5</sub> 3  |
| Curiosity Literacy     | CL <sub>6</sub>  | 1. Learning style provided the activities to create curiosity skill or a strong desire to know what the learners wanted based on the content of the subject and course description. The skill was created through the activities in searching the additional information from different sources. | CL <sub>6</sub> 1  |

|  |  |                                                                                                                                                                                                                |                   |
|--|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
|  |  | 2. Learning style provided the experiment in order to get the knowledge of the learners. Then the knowledge was discussed in the classroom by using the ability of the instructor through learning management. | CL <sub>6</sub> 2 |
|  |  | 3. Learning style was the learning management or teaching by embedding with the learners.                                                                                                                      | CL <sub>6</sub> 3 |

The analysis results of the factors of 2NAL model learning style gained from the study results and in-depth interview of the experts who analyzed the factors of 2NAL model learning style together were used to develop the model diagram of second order confirmatory factor of 2NAL model learning style in part 2 (as shown in the figure 2).Part.2.Results of Confirmatory Factor Analysis of 2NAL model



Chi-Square = 25.03, df = 51, P-value = 0.14,  
RMSEA = 0.00

**Fig. 2: The model diagram of second order confirmatory factor of 2NAL model learning Style**

From figure 2, the results of second order confirmatory factor analysis showed that the consistency between the model and the empirical data of 2NAL model learning style was at a good standard. Moreover, all goodness-of-fit statistics met the standards. The second order confirmatory factor analysis was used to confirm 2 issues as follows:

Issue 1: This was to confirm that the 18 observed variables were the subordinate factors of the main factors which consisted of 6 processes of 2NAL model learning style.

Issue 2: This was to confirm that the main factors mentioned above fit together to create the learning style of 2NAL model. All results showed that all observed variables were actually the subordinate factors of the main factors and the main factors actually fit together to create the learning style of 2NAL model, according to the statistical methods.

Goodness-of-fit statistics of the factor model and the empirical data was shown in the table 2.

**Table 2 : Goodness-of-fit statistics of the factor model and the empirical data**

| Goodness of Fit Index | Standard*   | Value | Result of Consideration | Conclusion |
|-----------------------|-------------|-------|-------------------------|------------|
| $\chi^2$ -test        | $p > 0.05$  | 0.14  | Passed                  | Good       |
| $\chi^2/df$           | $< 2$       | 0.49  | Passed                  | Good       |
| GFI                   | 0.95        | 1.00  | Passed                  | Good       |
| AGFI                  | 0.95        | 1.00  | Passed                  | Good       |
| NFI                   | ---         | 1.00  | Passed                  | Good       |
| CFI                   | $\geq 0.95$ | 1.00  | Passed                  | Good       |
| RMSEA                 | $\leq 0.05$ | 0.00  | Passed                  | Good       |
| SRMR                  | $\leq 0.05$ | 0.00  | Passed                  | Good       |
| RMR                   | $\leq 0.05$ | 0.00  | Passed                  | Good       |

\* (Suwanroj et al, 2019)

The table 2 showed that all goodness-of-fit statistics of the factor model and the empirical data met the standards by considering 2-test which was statistically non-significant ( $p = 0.14$ ),  $2/df = 0.49$ ,  $GFI = 1.00$ ,  $AGFI = 1.00$ ,  $NFI = 1.00$ ,  $CFI = 1.00$ ,  $RMSEA = 0.00$ ,  $SRMR = 0.00$  and  $RMR = 0.00$ . This also showed that the model from figure 2 matched the empirical data of the learning style of 2NAL model at a good standard. Then 6 processes of the learning style of 2NAL model were set priority in descending order. The results of the second order confirmatory factor analysis were used to confirm the quantitative data collected from the sample. The details were shown in the table 3.

Factor loading, Covariance and Priority of the Factor of the Learning styles of 2NAL model

**Table 3 :Factor loading, Covariance and Priority of Factors of Learning styles of 2NAL model**

| The Factor of the Learning styles | Factor loading |             | t             | R <sup>2</sup> | Priority of the Factor |
|-----------------------------------|----------------|-------------|---------------|----------------|------------------------|
|                                   | b              | S.E         |               |                |                        |
| <b>CL<sub>1</sub></b>             | <b>1.00</b>    | <b>0.01</b> | <b>27.91*</b> | <b>0.98</b>    | <b>1</b>               |
| CL <sub>1</sub> 1                 | 0.99           | 0.01        | 28.35*        | 0.97           |                        |
| CL <sub>1</sub> 2                 | 0.98           | 0.01        | 28.41*        | 0.96           |                        |
| CL <sub>1</sub> 3                 | 0.97           | 0.01        | 28.40*        | 0.98           |                        |
| <b>IL<sub>2</sub></b>             | <b>0.98</b>    | <b>0.01</b> | <b>27.30*</b> | <b>0.96</b>    | <b>2</b>               |
| IL <sub>2</sub> 1                 | 0.98           | 0.01        | 27.35*        | 0.95           |                        |
| IL <sub>2</sub> 2                 | 0.97           | 0.01        | 27.97*        | 0.94*          |                        |
| IL <sub>2</sub> 3                 | 0.96           | 0.01        | 27.61*        | 0.96           |                        |
| <b>DL<sub>3</sub></b>             | <b>0.97</b>    | <b>0.02</b> | <b>26.73*</b> | <b>0.95</b>    | <b>3</b>               |
| DL <sub>3</sub> 1                 | 0.97           | 0.01        | 26.70         | 0.97*          |                        |
| DL <sub>3</sub> 2                 | 0.96           | 0.01        | 26.65*        | 0.94           |                        |
| DL <sub>3</sub> 3                 | 0.95           | 0.02        | 26.47*        | 0.93           |                        |
| <b>SLL<sub>4</sub></b>            | <b>0.96</b>    | <b>0.02</b> | <b>26.75*</b> | <b>0.95</b>    | <b>4</b>               |
| SLL <sub>4</sub> 1                | 0.95           | 0.02        | 26.61         | 0.98*          |                        |
| SLL <sub>4</sub> 2                | 0.94           | 0.01        | 26.59*        | 0.95           |                        |
| SLL <sub>4</sub> 3                | 0.90           | 0.02        | 26.37*        | 0.96*          |                        |
| <b>CL<sub>5</sub></b>             | <b>0.95</b>    | <b>0.02</b> | <b>26.02*</b> | <b>0.95</b>    | <b>5</b>               |
| CL <sub>5</sub> 1                 | 0.95           | 0.02        | 26.61*        | 0.98*          |                        |
| CL <sub>5</sub> 2                 | 0.94           | 0.01        | 26.59*        | 0.95           |                        |
| CL <sub>5</sub> 3                 | 0.93           | 0.02        | 26.35*        | 0.96*          |                        |
| <b>CL<sub>6</sub></b>             | <b>0.94</b>    | <b>0.01</b> | <b>26.73*</b> | <b>0.95</b>    | <b>5</b>               |
| CL <sub>6</sub> 1                 | 0.92           | 0.01        | 26.71*        | 0.99*          |                        |
| CL <sub>6</sub> 2                 | 0.91           | 0.02        | 25.97*        | 0.95*          |                        |
| CL <sub>6</sub> 3                 | 0.90           | 0.01        | 24.30*        | 0.98*          |                        |

\*  $p < .01$

The table 3 showed the priority in descending order of the 6 processes of 2NAL model learning style which were new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai educational institutions. The results of the second order confirmatory factor analysis were used to confirm the quantitative data collected from the sample. The details were as follows:

First Process Factor of Content Literacy: CL<sub>1</sub>

CL<sub>1</sub> 1 (Learning styles had clear contents of the subject and was easy to learn by arranging the contents in order of difficulty.) was the variable with the highest factor loading at 0.95 and the covariance of Content Literacy factor was at 97%. CL<sub>1</sub> 2 (Learning styles consisted of different activities such as learning from work sheet or skill sheet applied from the contents of the subject by arranging the contents or activities in order of difficulty.) was the variable with the second highest factor loading at 0.98 and the covariance of Content Literacy factor was at 96%. CL<sub>1</sub> 3 (Learning pattern consisted of different activities and media platforms. The contents were interesting

and accurate.) was the variable with the third highest factor loading at 0.97 and the covariance of Content Literacy factor was at 98%, respectively.

#### Second Process Factor of Intelligence Literacy: IL<sub>2</sub>

IL<sub>2</sub> 1 (Learning style constructed responses and exchanges in different issues.) was the variable with the highest factor loading at 0.98 and the covariance of Intelligence Literacy factor was at 95%. IL<sub>2</sub> 2 (Learning style had clearly goal setting during learning management in order to create intelligence literacy.) was the variable with the second highest factor loading at 0.97 and the covariance of Intelligence Literacy factor was at 94%. IL<sub>2</sub> 3 (Learning style stimulated intellectual thoughts rationally and efficiently.) was the variable with the third highest factor loading at 0.96 and the covariance of Intelligence Literacy factor was at 96%, respectively.

#### Third Process Factor of Digital Literacy: DL<sub>3</sub>

DL<sub>3</sub> 1 (Learning style encouraged the learners to use digital media in learning management.) was the variable with the highest factor loading at 0.97 and the covariance of Digital Literacy factor was at 97%. DL<sub>3</sub> 2 (Learning style used online channels and tools to support learning management.) was the variable with the second highest factor loading at 0.96 and the covariance of Digital Literacy factor was at 94%. DL<sub>3</sub> 3 (Learning style helped the learners improve their digital competency both directly and indirectly.) was the variable with the third highest factor loading at 0.95 and the covariance of Digital Literacy factor was at 93%, respectively.

#### Forth Process Factor of Self Learning Literacy: SLL<sub>4</sub>

SLL<sub>4</sub> 1 (Learning style encouraged the learners to build the skill of self-learning process initiated by themselves based on their interests.) was the variable with the highest factor loading at 0.95 and the covariance of Self Learning Literacy factor was at 98%. SLL<sub>4</sub> 2 (Learning style created the skills in seeking learning sources and choosing learning methods.) was the variable with the second highest factor loading at 0.94 and the covariance of Self Learning Literacy factor was at 95%. SLL<sub>4</sub> 3 (Learning style provided self-assessment for learning progress and the learners could choose to do by themselves. This was the learning based on curiosity. The learners planned the learning by themselves.) was

the variable with the third highest factor loading at 0.90 and the covariance of Self Learning Literacy factor was at 96%, respectively.

#### Fifth Process Factor of Collaborative Literacy: CL<sub>5</sub>

CL<sub>5</sub> 1 (Learning style had an emphasis on working group. The learners were divided into small groups.) was the variable with the highest factor loading at 0.95 and the covariance of Collaborative Literacy factor was at 98%. CL<sub>5</sub> 2 (Learning style had an emphasis on different abilities of each member. They helped each other to reach the group's goal. They worked and shared responsibility.) was the variable with the second highest factor loading at 0.94 and the covariance of Collaborative Literacy factor was at 95%. CL<sub>5</sub> 3 (Learning style provided knowledge and experience exchanges between the members both in the classroom and on internet.) was the variable with the third highest factor loading at 0.93 and the covariance of Collaborative Literacy factor was at 96%, respectively.

#### Sixth Process Factor of Curiosity Literacy: CL<sub>6</sub>

CL<sub>6</sub> 1 (Learning style provided the activities to create curiosity skill or a strong desire to know based on the contents of the subject and course description. The skill was created through the activities in searching the additional information from different sources.) was the variable with the highest factor loading at 0.92 and the covariance of Curiosity Literacy factor was at 99%. CL<sub>6</sub> 2 (Learning style provided the experiment in order to get the knowledge of the learners. Then the knowledge was discussed in the classroom by using the ability of the instructor through learning management.) was the variable with the second highest factor loading at 0.91 and the covariance of Curiosity Literacy factor was at 95%. CL<sub>6</sub> 3 (Learning style was the learning management or teaching by embedding with the learners.) was the variable with the third highest factor loading at 0.90 and the covariance of Curiosity Literacy factor was at 98%, respectively. Factor Validity and Average Variance Extracted (AVE) of Learning Style Factors of 2NAL Model

Table 4 showed that 6 factors of 2NAL model learning style which were appropriate for new normal during COVID-19 pandemic had high validity when compared to the standard (more than .60). This was in line with the ideas of Suwanroj et al., (2019); Keith et al., (2018). The factors of 2NAL model style had high

**Table 3 :Factor loading, Covariance and Priority of Factors of Learning styles of 2NAL model**

A. Validity )c)

| Priority of the Factor | Standard* | Value | Consideration Result |
|------------------------|-----------|-------|----------------------|
| 1. CL <sub>1</sub>     | >0.60     | 0.99  | High validity        |
| 2. IL <sub>2</sub>     | >0.60     | 0.98  | High validity        |
| 3. DL <sub>3</sub>     | >0.60     | 0.98  | High validity        |
| 4. SLL <sub>4</sub>    | >0.60     | 0.96  | High validity        |
| 5. CL <sub>5</sub>     | >0.60     | 0.97  | High validity        |
| 6. CL <sub>6</sub>     | >0.60     | 0.99  | High validity        |

\* (Suwanroj et al, 2019; Keith et al., 2018)

B. Average Variance Extracted (AVE) )v)

| Priority of the Factor | Standard* | Value | Consideration Result |
|------------------------|-----------|-------|----------------------|
| 1. CL <sub>1</sub>     | >0.50     | 0.96  | High explanation     |
| 2. IL <sub>2</sub>     | >0.50     | 0.98  | High explanation     |
| 3. DL <sub>3</sub>     | >0.50     | 0.97  | High explanation     |
| 4. SLL <sub>4</sub>    | >0.50     | 0.96  | High explanation     |
| 5. CL <sub>5</sub>     | >0.50     | 0.97  | High explanation     |
| 6. CL <sub>6</sub>     | >0.50     | 0.98  | High explanation     |

\* (Suwanroj et al, 2019; Keith et al., 2018)

validity when considering the factor loading and the standard factor of the observed variables which latent variables were measured in each factor. The main factors could be used to explain the high variance of the variables in the factor when compared to the standard (more than 0.50). This was relevant to the ideas of Suwanroj et al., (2019); Keith et al., (2018). Thus the 6 factors of 2NAL model could be considered appropriate to use as the learning styles during COVID-19 pandemic for undergraduates of Thai educational institutions because based on the principle of statistic using confirmatory factor analysis, it proved that they had high validity.

## 5. Discussion

From the results, there were 3 main issues to discuss as follows:

**First Issue:** The study's results of 2NAL model factors gained from the literature review based on 12 ideas presented by Abdullaha et al. (2020); Alvermann et al. (2019); Artetxe et al. (2018); Barnett (2020); David et al. (2020); Gess-Newsome et al. (2019); Jake (2020); Markham (2020); Moreno-Guerrero et al.

(2020); Muthupoltotage et al (2018); Spruellet al. (2020); Suwanroj et al. (2019); and the synthesis of 2NAL model factors with the list of 18 observed variables to develop the learning factors of new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai educational institutions were in line with the research results presented by Barnett B. (2020); Suwanroj et al. (2019); Nayeem et al. (2018) in the part of using qualitative research to synthesize the knowledge in order to study the details and factors from academic documents, research or related literature to use as the research framework for the first phase.

**Second Issue:** The results of in-depth interview created to discuss about the factors of 2NAL model by a group of 9 experts from public and private educational institutions showed that the experts agreed and gave details about the factors of new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai Educational Institutions. Eighteen observed variables were provided from this step and were regarded as the subordinate factors of the main factors of new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai Educational Institutions. This learning model was named "2NAL model" and consisted of 6 factors as follows: 1) Content Literacy: CL<sub>1</sub> 2) Intelligence Literacy: IL<sub>2</sub> 3) Digital Literacy: DL<sub>3</sub> 4) Self Learning Literacy: SLL<sub>4</sub> 5) Collaborative Literacy: CL<sub>5</sub> and 6) Curiosity Literacy: CL<sub>6</sub>. The factor of Content Literacy was relevant to the research results presented by Barnett (2020); Gess-Newsome et al. (2019). The factor of Intelligence Literacy was relevant to the research results presented by Barnett (2020); David et al. (2020). The factor of Digital Literacy was relevant to the research results presented by Alvermann et al. (2019); Suwanroj et al. (2019); Abdullaha et al. (2020). The factor of Self Learning Literacy was relevant to the research results presented by Artetxe et al. (2018); Muthupoltotage et al. (2018). The factor of Collaborative Literacy was relevant to the research results presented by Moreno-Guerrero et al. (2020); Spruellet al. (2020). And the factor of Curiosity Literacy was relevant to the research results presented by Jake (2020); Markham (2020). These results of all 6 factors were relevant to the mentioned research in the aspect of using in-depth interview discussed by a group of experts. This was the methodology of the qualitative research to consider and confirm the details and factors to use as the conceptual framework. The academic documents, pieces of research or

related literature were studied to find the knowledge details which were considered and confirmed by a group of experts to get the knowledge to become more correct, accurate and complete.

Third Issue: The results of confirmatory factor analysis of 2NAL model were gained by using the methodology of the quantitative research to test the validity of the developed model measurement and to consider and confirm by using advanced statistics to test the validity of the model measurement which was developed from the 18 observed variables. It could say that 6 subordinate factors consisting of 1) Content Literacy: CL<sub>1</sub> 2) Intelligence Literacy: IL<sub>2</sub> 3) Digital Literacy: DL<sub>3</sub> 4) Self Learning Literacy: SLL<sub>4</sub> 5) Collaborative Literacy: CL<sub>5</sub> and 6) Curiosity Literacy: CL<sub>6</sub> were regarded as the factors of new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai Educational Institutions. The matching between the model and the empirical data collected by asking opinion from a group of experts of Thai educational institutions influenced all goodness of fit statistics to pass a criterion. These all showed that new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai Educational Institutions was useful and really matched the empirical data based on the context of Thai educational institutions from the expert's point of view. 2NAL model consisting of 6 factors and all observed variables which were considered and confirmed by using the confirmatory factor analysis could be used as the new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai Educational Institutions. The model and the empirical data were fit because all observed variables and the factors used to analyze were studied from the related documents and research (Abdullah et al., 2020; Alvermann et al., 2019; Artetxe et al., 2018; Barnett 2020; David et al., 2020; Gess-Newsome et al., 2019; Jake 2020; Markham, 2020; Moreno-Guerrero et al., 2020; Muthupoltotage et al., 2018; Spruellet al., 2020; Suwanroj et al., 2019) and really discussed by a group of experts to consider and confirm. (Selman et al., 2018) This model could be improved to be the new normal appropriate learning model during COVID-19 pandemic for undergraduates of Thai Educational Institutions based on the context of the educational institution for developing the most effective learning for the learners in the 21<sup>st</sup> century. Also, it could be used for the preparation of manpower development to meet an economic model: Thailand 4.0 which was relevant to

the research results presented by Suwanroj et al. (2019) who found that Digital Literacy was the necessary basis for the learners to create or to build on their knowledge.

## 6. Conclusion

From the development of the new normal appropriate learning style during the COVID-19 pandemic for undergraduates of Thai Educational Institutions, the learning style of 2NAL model was designed to be in line with the empirical data. This means that the factors of learning style of 2NAL model consisted of 6 main factors based on 18 observed variables. Each factor included 1) Content Literacy: CL<sub>1</sub> 2) Intelligence Literacy: IL<sub>2</sub> 3) Digital Literacy: DL<sub>3</sub> 4) Self Learning Literacy: SLL<sub>4</sub> 5) Collaborative Literacy: CL<sub>5</sub> and 6) Curiosity Literacy: CL<sub>6</sub>. These factors were really suitable for the context of the new normal appropriate learning style during COVID-19 pandemic for undergraduates of Thai Educational Institutions in the age of learning management on the digital world because the learning and teaching in the mentioned situation focused on bringing existed knowledge and competency to apply and improve the professional knowledge by meeting the need of the society through the appropriate and necessary learning styles. The educational institutions, therefore, have encouraged the instructors and learners to use the learning style which is appropriate with the context until the situation will unfold and go back to normal.

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# Effect of Computer Learning on performance in early Architecture Education

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**Abstract:** A mixed cohort of students with different experience backgrounds join the architecture degree. While some are well familiar with the user interface of computer and 3-D digital tools, others are not. The effect of such prior knowledge and their corresponding digital and analog performance in a designed experiment was evaluated with a sample of 38 first-year students. This was done to understand the performance effects of previous computer learning in students. Computer learning of the sample was studied in terms of years of computer exposure, the number of software known, and knowledge of 3D software or SketchUp. The results suggest that none of the factors contributed to the digital performance of students. This provided suggestions regarding the computer teaching emphasis which should be placed on students having less computer learning.

**Keywords:** Architecture Education; Sketching; Digital tools; digital performance; intuitive interface; Mental Imagery.

## 1. Introduction

The effect of technology on design education has led to an irreversible change that continues to grow stronger with time. The presence and acceptance of digital tools in design detailing, modelling, visualizing, and conception has become common practice to the extent that students lacking in either hardware or software requirements find themselves out of place in architecture studios. Such importance in the studio was earlier attributed to students having good sketching skills. The demand for software proficiency is even greater in the case of professional practice leading to students prioritizing the learning of tools as 3D max, Revit, Rhinoceros, especially towards the end of their degree. Earlier digital learning was a specific requirement of bachelor education which was fulfilled by dedicated software learning lectures. In times when the use and presence of computing systems were rare the college used to provide infrastructure to students through dedicated CAD labs and printing facilities. However, with laptops becoming more common and powerful they have omitted the need for such facilities in colleges which have gradually shifted towards using such spaces for 3D printing, sculpting needs. The importance of coding as an addition to most of the professional degrees has also shown its presence in the case of architecture. Architecture degree which already had a myriad of topics to choose from and fit in the five-year degree span has become more crowded due to the growing and changing needs of technology and the profession.

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Earlier students were expected to struggle with the new user interface of the screen, keyboard, and mouse. The problem is attributed to differences in affordances and feedback system of the analog vs the digital interface. Coupled with that each digital software has a different interface and set of affordances that need to be learned and practised. So that the cognitive load required to operate the digital interface minimizes leading to the free capacity being dedicated to the design problem at hand. Also according to the theory of distributed cognition externalization tools should help in serving several functions (Zhang & Patel 2006). The most pertinent being provision of short-term or long-term memory aids and provision of knowledge and skills that are unavailable from internal representations (Zhang & Patel 2006). These functions can only be realized if students can develop a certain amount of intuition/automation concerning software use. Intuitive designs allow for each action to provide relevant feedback leading to quick learning (Norman 2013). Most of the old software CAD, ArchiCAD, Revit, etc. do not have an intuitive user interface. To elaborate, if there is a group of actions that lead to feedback rather than a single action, this makes the interface non-intuitive. This delayed lag leads to extra cognitive load as some steps need to be automated without specific feedback leading to the requirement of mental models. These mental models become automatic with practice but they increase the learning curve of the representative (digital software) tool. Moreover, many times wrong mental models are formed in the early stages, due to personal software exploration which leads to increased cognitive costs later when it has to be modified (). Many times some software does not provide clear feedback or provide feedback with too much information, which if left unprocessed creates further confusion and need for corrections.

In such a scenario it becomes imperative to understand if the millennial students getting fresh admission are somehow more advantageous over those students who had less exposure to computers or vice versa. Such a revelation would provide pedagogic answers such as; whether providing pedagogic support would benefit students with less computer exposure.

## 2. Impact of Sketching and Physical Modelling in Design Learning

Sketching and physical modelling has been ranked as one of the most important factors affecting

creativity by 461 architecture graduate and post-graduate students (Daemei & Safari 2018). Additionally, in the case with drawing and sketching experience, it was seen that experts having developed skills were able to outperform their novices with less sketching experience (Kavakli et al. 2001). This has been attributed to the formation and exercise of mental imagery which helps in visual thinking, leading to better performance in ill-structured problems (Kavakli et al. 2001). There have also been reported cases of interactive mental imagery with experts who while solving a problem are continually shifting in between seeing, imaging, and drawing (Goldschmidt 1994). According to neuropsychology mental imagery has been linked to the generation, transformation, and inspection of images specifically related to spatial planning (Pearson et al. 2008; Kosslyn 2005). This provides mental imagery as a pertinent mental function for good design.

In design research, while using digital tools presence of mental imagery has not been reported so far. In a product design study, evaluative moves are said to increase while using digital tools, which indirectly point towards the presence of mental imagery (Lee et al. 2018). This paper, however, does not look for the presence of mental imagery directly rather it tries to evaluate the performance of students having previous computer learning to the ones with lesser learning. The finding can tentatively point towards the presence or absence of mental imagery connected to design.

## 3. Experiment Design

### A. Sample

The experiment was carried out on first-year students belonging to the architecture department at the Indian Institute of Technology Kharagpur. They were a total of 38 students with 10 females and 28 male students. Out of these 38 students, 16 had ten or more than ten years of computer exposure. Twelve students had an experience of five to nine years with computer usage. While ten students had less than five years of computer exposure. Of these, the students having more than nine years of computer exposure were considered as experts in computer usage while five to nine years were considered intermediate level users, and the last group was considered as computer novices. The experiment had two sessions with one being analog utilizing sketching and physical modelling tools and other utilizing SketchUp.

**Table 1: Classification of students according to years of computer exposure**

| Yrs. of comp. Expo. | No. of Students | Categorization |
|---------------------|-----------------|----------------|
| 0-4 yrs.            | 10              | Novice         |
| 5-9 yrs.            | 12              | Intermediate   |
| 10 yrs. beyond      | 16              | Expert         |

#### B. Question

The experiment question was a simple translation of a 2D graphic to its corresponding 3D options. The exercise was kept simple to ensure that the maximum cognitive load was generated due to the external representative tool. This would allow for easy identification of students who could produce several drawing transformations indicating that the cognitive load of the corresponding tool was less. The use of both analog and digital medium would also provide clarification over which tool should be preferred. Students having sufficient computer exposure were expected to outperform the ones with less experience. Three sets of these 2D drawings were created to ensure that students did not get influenced by each other while working and they had different questions during the two sessions. To ensure that the sets had the same problem difficulty the number of vertices and sides was kept similar.

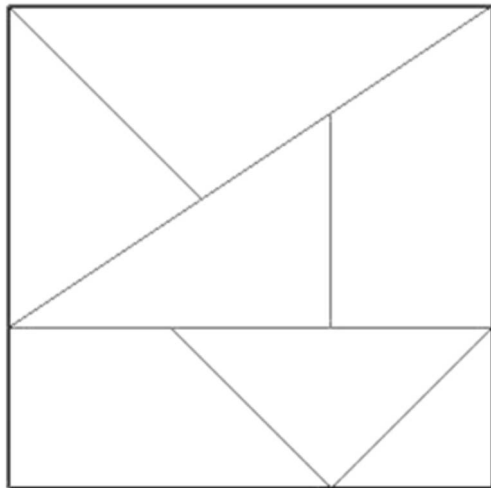


**Fig.1: 2D figure question used in experiment Set A**

Certain restrictions were imposed on the transformations to ensure that random generations and similar looking 3D geometry was avoided. The restrictions were as follows:

- Transformative moves were restricted to a cube

whose size was governed by the side of the 2D rectangle.

- No new points were to be created on the lines apart from the vertices/intersections provided in the 2D drawing.
- New lines were to be created in the Z-axis perpendicular or angled to the XY plane.
- The height of the perpendicular lines in the Z-axis could be equal or half of the side of the square.
- Lines or planes angled to the XY plane were to be created by using the 3D perpendicular lines.

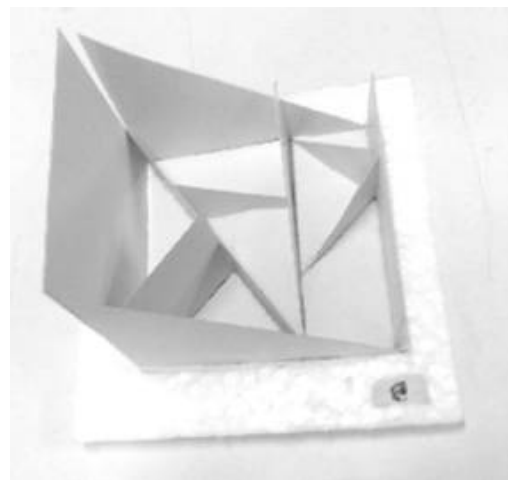


**Fig. 2: 3D options generated from 2D figures using analog medium**

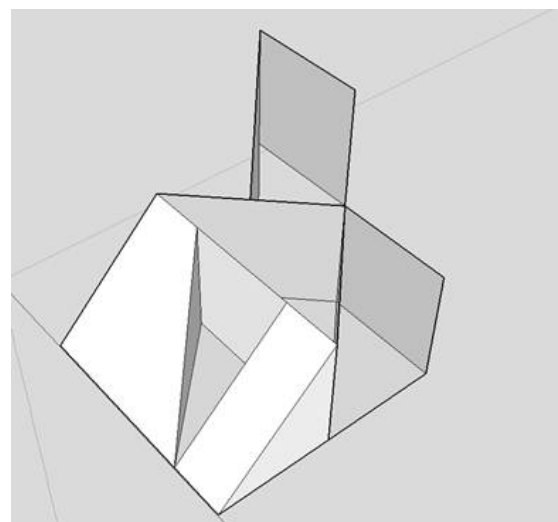


**Fig. 2: 3D options generated from 2D figures using analog medium**

For a transition from one 3D geometry to another, a minimum of two transformative moves had to be made.

### C. Tools

For analog, the students were provided with 2D drawings stuck on a thermocol base, and cardboards which could be easily inserted by making slits to create planes in the z-axis. While for digital tool Sketchup was used. The choice of software was based on its low learning curve, intuitive interface, and working similarity to analog tools. Students were provided with 2D drawing in Sketchup which was installed in separate computer systems of the CAD lab facility. Restrictions on the manipulation and creation of lines and points were provided to ensure that each 3D option created was significantly different from the other. A demonstration was provided to the students for analog tools, just before the onset of the exercise. In the case of Sketchup as most of the students were new to the software apart from two. A separate demonstration and doubt clarification session was held two weeks before the exercise. This time-lapse was to ensure that students had time to practice and get familiar with the Sketchup interface. A follow-up was also held to ensure that the students were practising in the interface with the necessary commands.

### D. Duration and other Details

The exercise session was restricted to 30 mins each. This time duration was kept less to ensure that students were not getting fatigued especially while using the digital tool. To reduce the effect of the order of exercises (confounding variable). Students were divided into two batches A and B randomly so that when A was performing the analog exercise, B was in the CAD lab with Sketchup exercise. This order was reversed in the second session. In the end, questionnaire feedback forms were filled by the students regarding the experiment and externalization tools.

## 4. Results

### A. Descriptive statistics

The data were analyzed in SPSS software. The mean of the total number of options generated for the sample population was 12.53. The standard deviation was 6.33. While the mean for total analog options generated was 6.76. The standard deviation was 4.7.

The mean number of digital options generated was 5.74 with a standard deviation of 3.1. Clear normal distribution was not seen for the frequency distribution of analog, digital, or total options. This kept the data analysis open to the use of non-parametric analysis of dependencies.

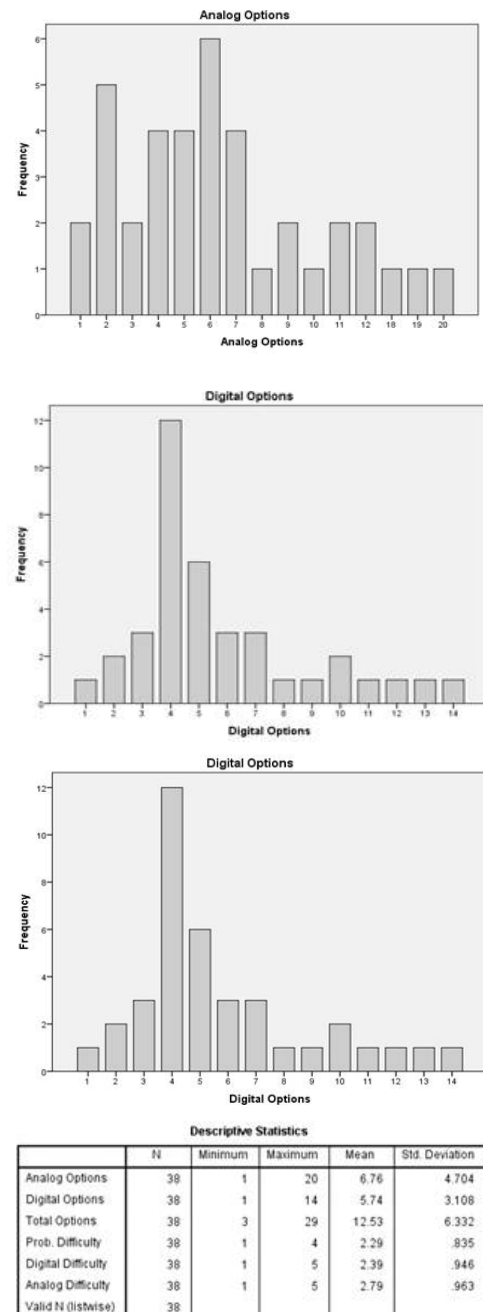


**Fig. 4: Descriptive Statistics related to results. (a) Frequency distribution of analog options generated in the experiment. (b) Frequency distribution of digital options generated in the experiment. (c) Frequency distribution of total options generated in the experiment (d) Descriptive statistics of data from the**

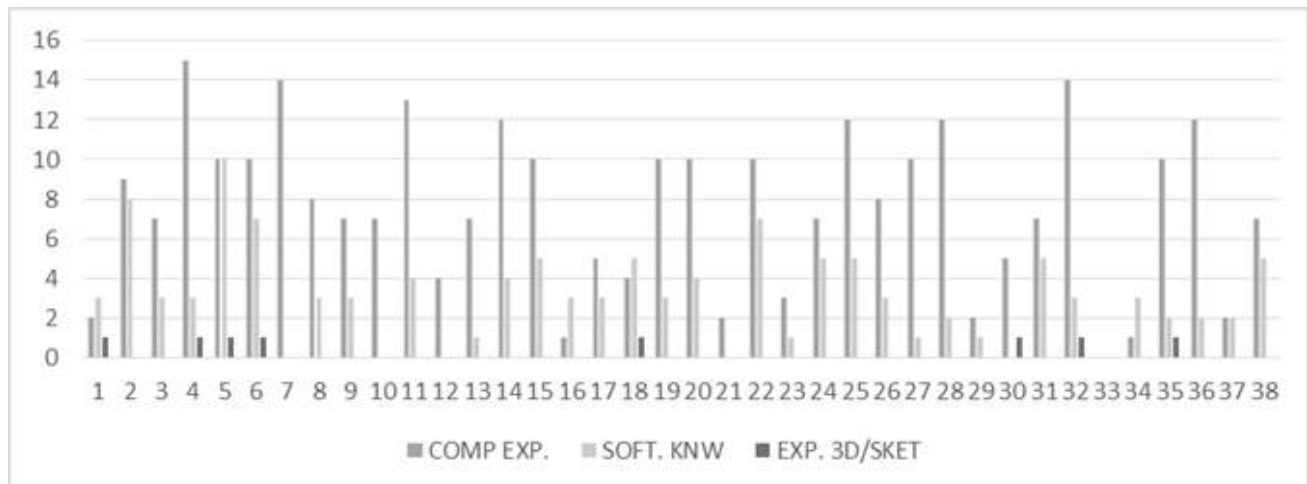


**Fig. 5: Previous Computer learning sample-wise data. COMP EXP. - Computer Exposure (yrs), SOFT. KNW. - Number of software known, EXP. 3D/SKET - Experience in 3D software or SketchUp**

B. Effect of previous computer learningFigure 5: Previous Computer learning sample-wise data. COMP EXP. - Computer Exposure (yrs), SOFT. KNW. - Number of software known, EXP. 3D/SKET - Experience in 3D software or SketchUp

The experiment was trying to find out the effect of previous computer learning on the digital performance of students. Previous computer learning was measured by three independent variables; computer exposure (years), number of software known; 3D/Sketchup experience. Exposure of 3D drafting and modelling was negligible in the sample population with eight having basic exposure to such software. Also, the experiment could have measured the effect of exposure to physical modelling and sketching experience. However, it was seen that the group was not well distributed with most of the students having some experience apart from four students. This prompted us to consider only number of years of computer exposure as one of the independent variables influencing the study. As discussed before more exposure would lead to intuitive behaviour towards the computer interface leading to better performance.

Kruskal Wallis test was used to analyze the variances between groups due to more than two groups present in most of the independent variables and their unequal sizes. Also the dependent variable data under analysis were not normally distributed with outliers which could not have been omitted. The results of Kruskal Wallis test revealed no statistically significant effect of computer exposure on digital performance of the students (Table 2). It should be noted that the students were divided into three groups; expert, intermediate, novice. Also the number of software known by the

students had no effect on their digital performance (Table 3). Further, the knowledge and experience of 3D software or Sketchup (used in the study) was also found to be statistically insignificant on the digital performance of students (Table 4). This tentatively points towards the absence or weak mental imagery formation while using digital 3D tools.

| Ranks           |                 |    |           |
|-----------------|-----------------|----|-----------|
|                 | Computer Exp.   | N  | Mean Rank |
| Digital Options | 0-4 years exp   | 10 | 22.50     |
|                 | 5-9 years exp   | 12 | 19.42     |
|                 | 10-15 years exp | 16 | 17.69     |
|                 | Total           | 38 |           |
| Analog Options  | 0-4 years exp   | 10 | 24.40     |
|                 | 5-9 years exp   | 12 | 16.83     |
|                 | 10-15 years exp | 16 | 18.44     |
|                 | Total           | 38 |           |

| Test Statistics <sup>a,b</sup> |                 |                |
|--------------------------------|-----------------|----------------|
|                                | Digital Options | Analog Options |
| Chi-Square                     | 1.199           | 2.809          |
| df                             | 2               | 2              |
| Asymp. Sig.                    | .549            | .245           |

a. Kruskal Wallis Test

b. Grouping Variable: Computer Exp.

**Fig. 6: SPSS table using Kruskal-Wallis test for effect of computer exposure (a) Ranks of Kruskal Wallis test (b) Test Statistics.**

| Ranks           |                |    |           |
|-----------------|----------------|----|-----------|
|                 | Software Known | N  | Mean Rank |
| Digital Options | 0              | 6  | 18.25     |
|                 | 1              | 4  | 26.88     |
|                 | 2              | 4  | 14.63     |
|                 | 3              | 11 | 21.36     |
|                 | 4              | 3  | 21.00     |
|                 | 5              | 6  | 11.92     |
|                 | 7              | 2  | 23.75     |
|                 | 8              | 1  | 36.00     |
|                 | 10             | 1  | 12.50     |
|                 | Total          | 38 |           |

Test Statistics<sup>a,b</sup>

|             | Digital Options |
|-------------|-----------------|
| Chi-Square  | 8.988           |
| df          | 8               |
| Asymp. Sig. | .343            |

a. Kruskal Wallis Test

b. Grouping Variable:  
Software Known

Fig. 7: SPSS table using Kruskal-Wallis test for effect number of software known (a) Ranks of Kruskal Wallis test (b) Test Statistics.

| Ranks           |                  |    |           |
|-----------------|------------------|----|-----------|
|                 | 3D/Sketchup Exp. | N  | Mean Rank |
| Digital Options | No experience    | 30 | 20.68     |
|                 | Experienced      | 8  | 15.06     |
|                 | Total            | 38 |           |

Test Statistics<sup>a,b</sup>

|             | Digital Options |
|-------------|-----------------|
| Chi-Square  | 1.677           |
| df          | 1               |
| Asymp. Sig. | .195            |

a. Kruskal Wallis Test

b. Grouping Variable:  
3D/Sketchup Exp.

Fig. 8: SPSS table using Kruskal-Wallis test for effect of 3D/Sketchup software known (a) Ranks of Kruskal Wallis test (b) Test Statistics.

## C. Other Results

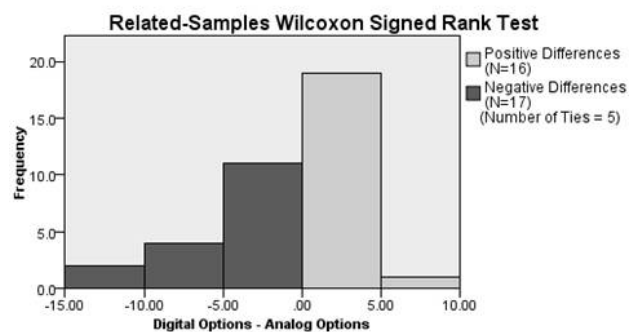
The study also tried to see if there was a medium that produced better results for 2D to 3D translation. To analyze this first a paired sample t-test was used. The analog and digital option variables, in this case, were considered as paired data since the questions for 2D to 3D translation were the same. Additionally, each student had done both the exercises in different sessions. However, since the variable data was not normally distributed and had outliers, a non-parametric test Wilcoxon Signed Rank test (WSRT) was also used. Results from both the tests pointed towards a statistically nonsignificant difference between using analog or digital medium for 2D to 3D translation. T-test had a significance level of 0.199 while WSRT has a significance of 0.337.

Hypothesis Test Summary

|   | Null Hypothesis                                                                | Test                                      | Sig. | Decision                    |
|---|--------------------------------------------------------------------------------|-------------------------------------------|------|-----------------------------|
| 1 | The median of differences between Analog Options and Digital Options equals 0. | Related-Samples Wilcoxon Signed Rank Test | .337 | Retain the null hypothesis. |

Asymptotic significances are displayed. The significance level is .05.

(a)



(b)

Fig. 9: Wilcoxon Signed rank test (Related-samples) for medium preference.(a) & (b) A Mann-Whitney test was also carried out to analyze the differences in performance between male and female sample population. The difference between their populations was statistically not significant. However, there was a big gap between the sample groups with 10 female students in a total of 38.

Test Statistics<sup>a</sup>

|                                | Total Options     |
|--------------------------------|-------------------|
| Mann-Whitney U                 | 90.000            |
| Wilcoxon W                     | 145.000           |
| Z                              | -1.662            |
| Asymp. Sig. (2-tailed)         | .097              |
| Exact Sig. [2*(1-tailed Sig.)] | .101 <sup>b</sup> |

a. Grouping Variable: Gender

b. Not corrected for ties.

(a)

| Ranks         |        |    |           |              |
|---------------|--------|----|-----------|--------------|
|               | Gender | N  | Mean Rank | Sum of Ranks |
| Total Options | Male   | 28 | 21.29     | 596.00       |
|               | Female | 10 | 14.50     | 145.00       |
|               | Total  | 38 |           |              |

(b)

**Fig.10: Mann-Whitney test for effect of gender on performance. (a) Test Statistics  
(b) Mann-Whitney test Ranks**

Similarly, the correlation between analog options and digital options produced by students was analyzed. Here again, a parametric and non-parametric test was used. For the parametric test, Pearson's coefficient was used. The test revealed a weak correlation (0.309) between analog and digital options generation with a statistical significance of 0.03. In the case of non-parametric test Spearman's rho was used which revealed a weaker correlation (0.288) with a higher significance of 0.04. The results indicate that the student's performance was in some way linked across the two medium options. In other words, the students who performed well in one medium did not perform poorly in the other medium. Here the effect of individual effort probably can explain a correlation between the two.

| Correlations   |                 |                         | Analog Options | Digital Options |
|----------------|-----------------|-------------------------|----------------|-----------------|
| Spearman's rho | Analog Options  | Correlation Coefficient | 1.000          | .309*           |
|                |                 | Sig. (1-tailed)         | .              | .030            |
|                |                 | N                       | 38             | 38              |
|                | Digital Options | Correlation Coefficient | .309*          | 1.000           |
|                |                 | Sig. (1-tailed)         | .030           | .               |
|                |                 | N                       | 38             | 38              |

\*. Correlation is significant at the 0.05 level (1-tailed).

**Fig. 11: Spearman's rho correlation between assessed problem difficulty and options (total/analog/digital) generated**

| Correlations    |                         |                         |               |                  |        |        |
|-----------------|-------------------------|-------------------------|---------------|------------------|--------|--------|
| Spearman's rho  | Analog Options          | Digital Options         | Total Options | Prob. Difficulty |        |        |
| Analog Options  | Correlation Coefficient | 1.000                   | .309          | .843**           | -.349* |        |
|                 | Sig. (2-tailed)         | .                       | .059          | .000             | .032   |        |
|                 | N                       | 38                      | 38            | 38               | 38     |        |
|                 | Digital Options         | Correlation Coefficient | .309          | 1.000            | .725** | -.314  |
|                 |                         | Sig. (2-tailed)         | .059          | .                | .000   | .055   |
|                 |                         | N                       | 38            | 38               | 38     | 38     |
| Digital Options | Total Options           | Correlation Coefficient | .843**        | .725**           | 1.000  | -.396* |
|                 |                         | Sig. (2-tailed)         | .000          | .000             | .      | .014   |
|                 |                         | N                       | 38            | 38               | 38     | 38     |
|                 | Prob. Difficulty        | Correlation Coefficient | -.349*        | -.314            | -.396* | 1.000  |
|                 |                         | Sig. (2-tailed)         | .032          | .055             | .014   | .      |
|                 |                         | N                       | 38            | 38               | 38     | 38     |

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

**Fig. 12: Spearman's rho (non-parametric) correlation test for relation between analog and digital options generated.**

Another finding was related to the assessed problem difficulty of 2D to 3D translation and total options generated by the students. A Spearman's Rho test for

correlation revealed a negative co-relation of 0.396 with a significance of 0.014. This points out that students who assessed the experiment problem to be difficult produced more number of 3D options. This is counter-intuitive and could be explained based on the behavioural psychology of the students. They exerted more effort when they found that the problem was difficult. Individually analog options correlation stood at -0.349 with a significance of 0.032 while for digital options the correlation was -0.314 with a significance of 0.055.

## 5. Discussion & Conclusion

The experiment was carried out to study the effect of previous computer learning on early architecture education. A designed experiment that required students to translate 2D to possible 3D options using both analog and digital mediums was used. The study was carried out on a sample size of 38. Previous computer learning data was collected in terms of exposure to the computer (years), software known, and exposure to 3D/Sketchup software. All these variables were found to be statistically insignificant on the digital and overall performance of the students in the experiment. This somehow indicated that there was no additional need for colleges to invest time and resources into training and preparing students with no previous computer learning.

Apart from these main findings, some other effects were also studied

- The first one being the performance effect of the medium (analog or digital). No statistically significant difference was found between the two mediums used by students for 2D to 3D translation.
- The effect of gender was also insignificant to the total option generated by each sample.
- It was found that the students' performance did not drastically change while switching in between mediums.
- The students' performance and their rating of problem difficulty were negatively related, with anticipation of the difficult problem leading to better performance.

The results of the effect of knowledge of a 3D digital tool also were insignificant, tentatively pointing towards the absence or weak mental imagery

formation while using digital 3D tools. However, the results of this study were limited to an institution with small sample size, replication of results would lead to external validation of conclusions on a larger population. The method adopted in the study was experimental and tried to reduce the effect of other influencing variables by making the exercise different from real-studio setting. This could also affect the ecological validity of the findings.

The learning and practice of computers did not impact the performance of student's unlike the case of sketching and physical modelling in design education. There have been various studies pointing towards the benefit of sketching and physical modelling in developing mental imagery. However, so far no study had looked into the effect of computer learning and software knowledge on the internal representation of designers. The paper addressed the gap in research and pointed towards a possibility where mental imagery could be weak while using 3D digital tools. Design learning as taught in the architecture studio aims to develop mental imagery and related design knowledge (Eastman 2001). Conceptual phase of design which is directed by manual sketching leads to the deployment of mental imagery, resulting in enhanced visual perception and reflective conversations (Goldschmidt 1994; Goldschmidt 1995; Schon and Wiggins 1992). According to the findings, the use of computer for design learning and conceptual design could be restrictive. More study needs to be done in this direction to ascertain or clarify the findings.

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## Fuzzy AHP-TOPSIS approaches to prioritize teaching solutions for Intellect Errors

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**Abstract:** The teaching fraternity and intellects play an important role in students' careers as they make students industry-ready. During their teaching, they make different types of errors. One of the neglected aspects during teaching is intellect errors and these directly or indirectly impact students learning capabilities. The scattered literature shows that there are twelve types of intellect errors like 'error of coincidence', 'senses error', 'analogy error', 'subjectivity error', etc. To minimize these errors, six solutions have been identified like 'selection of right instruments', 'development of critical thinking in the students', 'aware about knowledge engineering development' etc. This study aims to identify and prioritize the solutions to overcome the errors of the intellect that has been the ignored aspect of the teaching till now. A hybrid approach of fuzzy AHP (Analytical Hierarchy Process) and Fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) has been proposed to rank the solutions that minimize the intellect errors. Fuzzy AHP is used to compute the weights for intellect errors by doing the pairwise comparison and fuzzy TOPSIS is used to rank the identified solutions with the help of generated weights of fuzzy AHP. The results show that "error of proximity" and "senses error" are the highest and least rated intellect errors respectively. The

topmost rated solution to handle errors of the intellect is "development of critical thinking in the students".

**Keywords:** Intellect errors, fuzzy AHP, fuzzy TOPSIS, industry-ready

### 1. Introduction

Intellects are working on the students to make them industry-ready. Instead of progression and expansion in education and technology developments, industry experts always complain students lack analytical as well as critical thinking skills. Some of these lacking skills may be the result of errors done by the intellects. Intellect errors can be wrenching out at the wrong interpretations by looking at insufficient as well as incorrect data and then looking at the literature to support these interpretations. This will result in inaccurate deductions and theories. The intellects have to go the other way around i.e. correct interpretations of the data should be taught in the class instead of neglecting the incorrect data (Palanki, 2021). In C programming books, generally, you find a program to calculate Armstrong's number of three-digit numbers. It is calculated by finding out the overall sum of the cube of each digit in the three-digit number. If this sum is equal to the original number, then it is Armstrong's number. This is true for three-digit numbers and intellects generally do the same thing for four-digit, five-digit, etc. numbers but the truth is it is calculated by finding out the overall sum of the power of the "number of digits" of each digit in the number. This

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wrong concept is also carried by students in the industry work too. One other type of intellect error by the intellects is that when students show programming programs to the teachers, they neglect the proper formatting, comments, and rules that are necessary for proper readability and documentation of the programs. This lack of professional skills is developed in the students unknowingly whereas this is one of the most important skills as industries are too focused-on documentation and rules for writing programs. The important thing is to firstly inculcate skills like analytical, reasoning, critical thinking, and troubleshooting skills in the students before making them industry-ready. If these skills are not given to the students, then it leads to disasters in the projects like manufacturing industries, medical treatment, budget handling, research development and results in high upfront and operational project costs, delayed time, poor usage of resources and infrastructures. Section 2 describes different types of intellect errors whereas section 3 deals with the solutions that minimize the intellect errors. Section 4 discusses the research methodology in which fuzzy AHP and fuzzy TOPSIS have been described with their implementation procedure. Section 5 of the current study targets the conclusions.

## 2. Intellect Errors

The life of a human consists of seven attributes (Revel Miller, 2019). The attributes are self-aspect, emotional aspect, social aspect, spiritual aspect, physical aspect, behavioral aspect, and mental aspect. These seven aspects are the pillars of human beings' life. These aspects are directly or indirectly related to emotions, drives for eating & sleeping as well as thinking levels and innovations. With these aspects, intellect errors are also associated (Palanki, 2021) and these are mentioned as:

### A. Error of coincidence

This is also called 'Post hoc fallacy' or 'Post hoc ergo propter hoc'. This fallacy states that "Event Q" has occurred due to "Event P" or in other words it can be said that event Q has occurred after the occurrence of event P. But, both events P and Q are independent of each other. In this type of error, it is also assumed that one event is a cause and the other event is an effect. It is just a coincidence. Suppose you went out of the house and it rains. It does not mean when you go out, it will rain. In the first stance, it is just a coincidence. Sometimes, intellects do the error of coincidence

while giving lectures. They give explicit reasoning for the acts that intellects should not work on, but they tell post hoc stories to justify their acts (Summers, 2017).

### B. Error of proximity

This is also called "order-effect". It occurs when a person does the rating on one item and it affects the rating of other items that immediately comes after it (Javidmehr & Ebrahimpour, 2015). Suppose we buy mangoes from a particular shop and every time they are good in quality but maybe sometimes rotten mangoes can be bought from that shop, this is an example of proximity error. Suppose that interviewer knows particular university students are brilliant in programming and every time they are selected and a weak programming student can clear the interview as the interviewer has a perception that these students have high programming skills. This is another example of intellect proximity error.

### C. Senses error

The author (Patterson, 2016) stated that sometimes senses deceive and that is the reason why we should not fully believe in the senses. Look when intellects try to differentiate between different micro-organisms with the naked eye, they are failed to do. For differentiating micro-organisms, a microscope is required. This statement states that the important thing is to choose the right instrument for a given problem to minimize the senses' error.

### D. Error of ignorance

Intellects do this error as they perceive they know everything but actually, they do not know or in other words, it can be said that decision-makers believe that some outcomes may occur but in the end, these outcomes do not occur, these are ignorance errors committed by the intellects (Wolfson & Carroll, 1976). These types of errors when committed in the industry then the loss is high.

### E. Error of habit

When a man sees a small stone on the road, he has the habit of hitting the stone with his foot and when he inadvertently hit a large stone with his foot, he injured his foot. This is an example of an 'error of habit'. Suppose an examiner gives very few marks to a tougher programming question and suddenly a good answer comes his way but he again gives very few marks. This is an example of an 'error of habit'.

#### F. Generalization error

The experts are examining the intellects of ten persons of a town and they find that all ten people are below average. Here, experts can conclude that all the persons of this town are below average in intellects. This type of generalization error should be avoided when the sample size is very less and a conclusion is made for the whole population. To minimize this type of error, discussions, and sharing of information should be encouraged (Nadeau & Bengio, 2003).

#### G. Error of the bandwagon

Due to external pressure, a decision is accepted or rejected. This effect is a bandwagon. Suppose you want to buy a bike based on its average and then you do a survey and you find bike “A” has more average as mentioned in its advertisement and all people will also support that too. This feature can be one of the top criteria for selecting a bike but one must list down all the cons of this particular bike before buying the bike. By using this technique, the error of the bandwagon can be minimized.

#### H. Familiarity Error

This error occurs when the problem was familiar and people just ignore and it becomes a calamity. Let's take a case when a family knows when they switched on the TV, there are small sparks in wires and all family members are ignorant to this and later on, this small spark leads to fire in the house. This type of error is a familiarity error.

#### I. Subjectivity Error

When an individual makes a decision, there are chances of bias and it leads to subjective error. To minimize the subjective error, group decision-making, brainstorming, or Delphi techniques are preferred. Decision-making improves when group-decision making takes place.

#### J. Analogy Error

Many experts use an analogy to enhance a better understanding of the concepts but this does not prove the hypothesis. This is just used for understanding. For example, when you reap good things, you will get good things in return.

#### K. Error of irrelevance

When a certain argument is taking place and the critics talk about the problems that are not associated with that argument. This is an ‘error of irrelevance’. Suppose a researcher writes a paper on Rice Hispa disease identification and the reviewer tells to survey rice soil and that is irrelevant to this particular disease as it is not associated with soil at all. This is an ‘error of irrelevance’.

#### L. Error of the machine

The researchers are using machine learning and deep learning models on the collected datasets without understanding why they are using these techniques. This leads to wrong interpretations.



Fig. 1: Types of Intellect Errors

### 3. Possible Teaching Solutions of Intellect Errors

Several teaching solutions can be used for minimizing the intellect errors and these are listed as:

- a) Development of critical thinking skills in the students (Renatovna, 2019), (Rahmawati & Harun, 2019), (Bezanilla, Fernández-Nogueira, Poblete, & Galindo-Domínguez, 2019), (Palanki, 2021).
- b) Intellects should be aware of knowledge engineering developments (Palanki, 2021).
- c) Intellects should have good communication skills and be team collaborators (Bambaeeroo & Shokpour, 2017), (Palanki, 2021).

d) Follow ethical practices (Sherpa, 2018), (Kusumaningrum, Sumarsono, & Gunawan, 2019), (Palanki, 2021).

e) Teachers should be innovative, flexible, and learners (Kalyani & Rajasekaran, 2018), (Palanki, 2021).

f) Selection of right instruments for teaching (Rahmawati & Harun, 2019), (Palanki, 2021).

#### 4. Research Methodology

The literature shows that the researchers have not explored much about intellect errors and their solutions. Thus, there is a need to identify, analyze and prioritize intellect errors. At the same time, different solutions have been proposed by the researchers to overcome these intellect errors but these solutions are very much scattered in the literature. There is a need to collect, organize and analyze these solutions that will help the Intellects and students to minimize the mistakes in their decision-making process. Hybrid fuzzy AHP and fuzzy TOPSIS have been used in the current study to prioritize the solutions for minimizing intellect errors. The intellect errors and the solutions are described in Section 2 and Section 3 respectively. Fuzzy AHP is applied to acquire the weights of the intellect errors and these weights are used by fuzzy TOPSIS for ranking the solutions that will be best suited to minimize the intellect errors. The choice of current methodology that uses hybrid fuzzy AHP-TOPSIS approach is supported by several motives and these are listed as:

- Ranking of Intellect errors and their solutions comes under the category of multi-criteria decision making. This involves human judgments that are mostly subjective and unclear. It becomes problematic to represent these judgments in numerical values, so to handle the imprecision, ambiguity, and vagueness in the judgments appropriately fuzzy-based methods are used.
- This hybrid approach improves a significant amount of time in computations when compared with other decision-making approaches like elimination & choice expressing reality (ELECTRE), interpretive structural modeling (ISM), and analytic network process (ANP).
- Both these approaches are quite simple in understanding, conception, and application.

- The main reason for electing this hybrid approach is due to its suitability to handle the complex multi-decision environment.

#### 4.1 Fuzzy AHP

The fuzzy AHP procedure consists of many strides and these are taken from the study (Chang, 1996). The strides are described as:

Stride 1: Initially, a pairwise matrix is prepared using triangular fuzzy numbers (TFNs). The expert opinions are taken into account along with equation (1) to make this pairwise matrix.

$$\tilde{E} = \begin{bmatrix} 1,1,1 & \tilde{e}_{12} & \tilde{e}_{13} & \tilde{e}_{14} & \cdots & \tilde{e}_{1n} \\ \tilde{e}_{21} & 1,1,1 & \tilde{e}_{23} & \tilde{e}_{24} & \cdots & \tilde{e}_{2n} \\ \tilde{e}_{31} & \tilde{e}_{32} & 1,1,1 & \tilde{e}_{34} & \cdots & \tilde{e}_{3n} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{e}_{n1} & \tilde{e}_{n2} & \tilde{e}_{n3} & \tilde{e}_{n4} & \cdots & 1,1,1 \end{bmatrix} \quad (1)$$

where  $\tilde{e} = (a_{xy}, b_{xy}, c_{xy})$  and  $x, y = 1, 2, 3, \dots, n$  are triangular fuzzy numbers.

Stride 2: Fuzzy synthetic extent values (FVs) are reckoned with the help of equation number 2.

$$FV_x = (\sum_{y=1}^n a_y, \sum_{y=1}^n b_y, \sum_{y=1}^n c_y) * (\frac{1}{\sum_{x=1}^n c_x}, \frac{1}{\sum_{x=1}^n b_x}, \frac{1}{\sum_{x=1}^n a_x}) \quad (2)$$

Stride 3: Here, the Degree of possibility (DPos) is computed.

Stride 4: Calculation of fuzzy weight (FuzW) and non-fuzzy weight (NFuzW) for all intellect errors is done.

#### 4.2 Fuzzy AHP Implementation

The abbreviations for all Intellect errors have been mentioned in Annexure A. Firstly in fuzzy AHP, the experts' linguistic assessment method is described for rating all the

**Table 1 : Fuzzy Linguistic Scale used for pairwise decision**

| Linguistic Term                                       | TFNs (a,b,c)          | Linguistic Term                                   | TFNs (a,b,c)          |
|-------------------------------------------------------|-----------------------|---------------------------------------------------|-----------------------|
| Equal                                                 | $\tilde{1} = (1,1,1)$ | Moderate                                          | $\tilde{3} = (2,3,4)$ |
| Strong                                                | $\tilde{5} = (4,5,6)$ | Very Strong                                       | $\tilde{7} = (6,7,8)$ |
| Tremendous                                            | $\tilde{9} = (9,9,9)$ | Intermediate value between Equal and Moderate     | $\tilde{2} = (1,2,3)$ |
| Intermediate value between Moderate and Strong        | $\tilde{4} = (3,4,5)$ | Intermediate value between Strong and Very Strong | $\tilde{6} = (5,6,7)$ |
| Intermediate value between Very Strong and Tremendous | $\tilde{8} = (7,8,9)$ |                                                   |                       |

intellect errors as shown in table 1. Table 1 consists of nine linguistic terms along with an associated TFN that will be used by the decision-makers for pairwise comparison of intellect errors. 15 experts have given their opinions for

making a pairwise decision comparison matrix using equation 1. Table 2 shows the aggregated values of the decision matrix values mentioned by the different experts.

**Table 2: Calculated Intellect Errors fuzzy aggregated decision matrix**

|      | EC               | EP               | ----- | ----- | ----- | EIr              | EM                |
|------|------------------|------------------|-------|-------|-------|------------------|-------------------|
| EC   | (1,1,1)          | (0.23,0.31,0.44) | ----- | ----- | ----- | (2.00,3.00,4.00) | (1.89,2.33, 3.00) |
| EP   | (2.33,3.33,4.33) | (1,1,1)          |       |       |       | (5.00,6.00,7.00) | (1.78,2.13,2.50)  |
| SE   | (1.08,1.78,2.50) | (2.08,2.78,3.50) |       |       |       | (0.20,0.25,0.33) | (1.80,2.17,2.56)  |
| EIg  | (2.71,3.38,4.06) | (2.08,2.78,3.50) |       |       |       | (2.00,3.00,4.00) | (0.33,0.50,1.00)  |
| EH   | (0.23,0.31,0.44) | (1.71,2.39,3.07) |       |       |       | (2.00,3.00,4.00) | (3.44,4.17,5.00)  |
| GE   | (0.73,1.42,2.11) | (2.71,3.39,4.07) |       |       |       | (0.25,0.33,0.50) | (2.00,3.00,4.00)  |
| EB   | (1.42,2.11,2.83) | (3.67,4.67,5.67) |       |       |       | (0.33,0.50,1.00) | (1.89,2.29,3.05)  |
| FE   | (0.25,0.33,0.50) | (0.14,0.17,0.20) |       |       |       | (2.00,3.00,4.00) | (1.89,2.33,3.00)  |
| SubE | (1.00,2.00,3.00) | (2.75,3.44,4.17) |       |       |       | (2.00,3.00,4.00) | (1.89,2.33,3.00)  |
| AE   | (1.38,2.06,2.73) | (1.10,1.44,1.80) |       |       |       | (2.00,3.00,4.00) | (2.00,3.00,4.00)  |
| EIr  | (0.25,0.33,0.50) | (0.14,0.17,0.20) |       |       |       | (1,1,1)          | (2.00,3.00,4.00)  |
| EM   | (0.71,1.39,2.07) | (2.71,3.39,4.07) |       |       |       | (0.25,0.33,0.50) | (1,1,1)           |

Table 3 have FVs for all intellect errors and it is calculated by the use of extent analysis method and for the computation, equation 2 is used.

**Table 3: Fuzzy Synthetic extent values of all criteria**

| Fuzzy Synthetic Criteria (FC) | Fuzzy Synthetic Extent Values (FVs) |
|-------------------------------|-------------------------------------|
| FC1 (EC)                      | a1=0.05, b1=0.08, c1=0.15           |
| FC2 (EP)                      | a2=0.07, b2=0.12, c2=0.19           |
| FC3 (SE)                      | a3=0.03, b3=0.06, c3=0.10           |
| FC4 (EIg)                     | a4=0.05, b4=0.08, c4=0.14           |
| FC5 (EH)                      | a5=0.04, b5=0.07, c5=0.13           |
| FC6 (GE)                      | a6=0.05, b6=0.09, c6=0.16           |
| FC7 (EB)                      | a7=0.06, b7=0.10, c7=0.17           |
| FC8 (FE)                      | a8=0.05, b8=0.08, c8=0.15           |
| FC9 (SubE)                    | a9=0.05, b9=0.10, c9=0.18           |
| FC10 (AE)                     | a10=0.05, b10=0.10, c10=0.19        |
| FC11 (EIr)                    | a11=0.03, b11=0.06, c11=0.10        |
| FC12 (EM)                     | a12=0.03, b12=0.06, c12=0.12        |

After performing this stride, the minimum degree of possibility (DPos) is computed as shown in table 4. This step is used to find the greatest fuzzy value among several fuzzy numbers. It is calculated using equations 3, 4, and 5.

**Table 4: Calculated Degree of possibility for all criteria**

|          | V(FC1) | V(FC2) | V(FC3) | V(FC4) | V(FC5) | V(FC6) | V(FC7) | V(FC8) | V(FC9) | V(FC10) | V(FC11) | V(FC12) |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| DPos     | 0.72   | 1.00   | 0.66   | 0.95   | 0.88   | 1.00   | 1.00   | 0.99   | 1.00   | 1.00    | 0.67    | 0.75    |
|          | 1.00   | 1.00   | 0.33   | 0.64   | 0.57   | 0.79   | 0.85   | 0.71   | 0.84   | 0.91    | 0.36    | 0.45    |
|          | 1.00   | 1.00   | 0.71   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00    | 0.99    | 1.00    |
|          | 1.00   | 1.00   | 0.78   | 1.00   | 0.93   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00    | 0.72    | 0.80    |
|          | 0.93   | 1.00   | 0.59   | 0.88   | 0.81   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00    | 0.79    | 0.86    |
|          | 0.88   | 1.00   | 0.53   | 0.81   | 0.74   | 0.94   | 1.00   | 0.93   | 1.00   | 1.00    | 0.61    | 0.69    |
|          | 1.00   | 1.00   | 0.67   | 0.95   | 0.89   | 1.00   | 1.00   | 0.87   | 0.99   | 1.00    | 0.54    | 0.62    |
|          | 0.90   | 1.00   | 0.57   | 0.84   | 0.77   | 0.96   | 1.00   | 0.89   | 1.00   | 1.00    | 0.69    | 0.76    |
|          | 0.83   | 1.00   | 0.49   | 0.77   | 0.70   | 0.89   | 0.95   | 0.82   | 0.94   | 1.00    | 0.58    | 0.66    |
|          | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00    | 0.51    | 0.59    |
|          | 1.00   | 1.00   | 0.94   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00    | 0.94    | 1.00    |
| Min DPos | 0.72   | 1.00   | 0.33   | 0.64   | 0.57   | 0.79   | 0.85   | 0.71   | 0.84   | 0.91    | 0.36    | 0.45    |

$$V(FC1 \geq FC2) = 1 \text{ iff } b1 \geq b2 \quad (3)$$

$$V(FC1 \geq FC2) = 0 \text{ iff } a1 \geq c2 \quad (4)$$

$$V(FC_2 \geq FC_1) = \frac{a_1 - c_2}{(b_2 - c_2) - (b_1 - a_1)} \quad (5)$$

Now, the next step is to calculate the Fuzzy weight (FuzW), non-fuzzy weight/normalized weight (NFuzW) using equation 6 and equation 7.

$$NFuzW = (d'(Q1), d'(Q2), d'(Q3), d'(Q4), \dots, d'(Qn))^T \text{ where } d'(Qi) = \min V(FCa \geq FC_b) \text{ \& } a, b = 1, 2, 3, \dots, n \text{ and } a \neq b \quad (6)$$

$$FuzW = (d(Q1), d(Q2), d(Q3), d(Q4), \dots, d(Qn))^T \quad (7)$$

After the computation of weights, they are ranked according to their weights. The highest weight incurred is ranked highest and the lowest weight incurred is ranked lowest among all intellect errors as mentioned in Table 5.

**Table 5: Ranking of Intellect Errors**

| Criteria | Normalized Weights | Ranking of Criteria |
|----------|--------------------|---------------------|
| EC       | 0.088              | 6                   |
| EP       | 0.122              | 1                   |
| SE       | 0.040              | 12                  |
| Elg      | 0.079              | 8                   |
| EH       | 0.070              | 9                   |
| GE       | 0.097              | 5                   |
| EB       | 0.104              | 3                   |
| FE       | 0.087              | 7                   |
| SubE     | 0.103              | 4                   |
| AE       | 0.112              | 2                   |
| Elr      | 0.044              | 11                  |
| EM       | 0.055              | 10                  |

### 4.3 Fuzzy TOPSIS

TOPSIS is defined as the compensatory accumulation method that found the best alternative by calculating the geometric distance that is shortest towards the positive ideal solution (PIS) and farthest from the negative ideal solution (NIS) after identifying weights and normalizing each criterion score. The experts find it very difficult to assign a crisp number rating to the alternatives for the attributes. Fuzzy TOPSIS is used in this to handle experts uncertain judgments vagueness and linguistic judgments by providing relative importance to the attributes by using fuzzy numbers (Patil & Kant, 2014), (Sirisawat & Kiatcharoenpol, 2018), (Singh & Sarkar, 2019), (Rampasso et al., 2019). The authors (Huang & Yoon, 1981) have introduced this concept and is one of the prevalent approaches of multi-criteria.

The steps involved in this approach are described below:

Step 1: Create fuzzy matrix using linguistic assessment as mentioned in table 1 and rate each teaching solution of intellect errors. In the current

study, 15 experts rated six solutions for 12 intellect errors. The abbreviations for all solutions have been mentioned in Annexure B.

Step 2: Compute the aggregate fuzzy matrix (see table 6) for taking inputs from 15 experts.

The aggregate function is used to aggregate the opinions of all experts is shown in equation 8.

$$F = \min(\sum_{q=1}^q d_{ijq}), c = 1/q \sum_{q=1}^q e_{ijq}, f = \max(\sum_{q=1}^q f_{ijq}) \quad (8)$$

Step 3: Now, do the normalization of aggregated function which is shown in table 7.

Step 4: Compute the weighted fuzzy evaluation matrix using equation 9 for all six solutions. The results are shown in Table 8.

$$\begin{aligned} \tilde{N} &= \text{Normalized fuzzy matrix} * W_j \\ \tilde{N} &= [\tilde{N}_{ij}]_{s \times t} \quad i = 1, 2, \dots, s, \quad j = 1, 2, \dots, t \quad \text{where} \\ \tilde{N}_{ij} &= \tilde{r}_{ij}(\cdot) W_j \end{aligned} \quad (9)$$

Step 5: Calculate the fuzzy positive ideal solution ( $A^*$ ) and fuzzy negative ideal solution ( $A^-$ ) for each solution using equation 10 and equation 11 respectively.

$$A^* = (\tilde{N}_1^*, \tilde{N}_2^* \dots \dots \tilde{N}_n^*) \quad \text{where } \tilde{N}_j^* = (\tilde{c}_j^*, \tilde{c}_j^*, \tilde{c}_j^*) \quad \text{and} \quad \tilde{c}_j^* = \max_i \{\tilde{c}_{ij}\} \quad (10)$$

$$A^- = (\tilde{N}_1^-, \tilde{N}_2^- \dots \dots \tilde{N}_n^-) \quad \text{where } \tilde{N}_j^- = (\tilde{c}_j^-, \tilde{c}_j^-, \tilde{c}_j^-) \quad \text{and} \quad \tilde{c}_j^- = \min_i \{\tilde{c}_{ij}\} \quad (11)$$

Step 6: The distance of each solution from  $A^*$  and  $A^-$  is calculated using equations 12 and 13.

$$F_i^+ = \sum_{j=1}^n dv(\tilde{N}_{ij}, \tilde{N}_j^*) \quad i = 1, 2, \dots, m \quad (12)$$

$$F_i^- = \sum_{j=1}^n dv(\tilde{N}_{ij}, \tilde{N}_j^-) \quad i = 1, 2, \dots, m \quad (13)$$

Step 7: Determine the closeness of coefficient (CCi) using equation 14 and rank the solutions based on the values of CCi. The results are mentioned in table 9.

**Table 6: Calculated Fuzzy aggregated Evaluation Matrix for Intellect Solutions**

|      | EC         | EP         | SE         | Elg        | EH         | GE         | EB         | FE         | SubE       | AE         | Elr        | EM         |
|------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| IFL  | (1,4,7)    | (5,6,7)    | (5,6,7)    | (2,4,7)    | (3,5,33,7) | (1,5,33,9) | (5,6,7)    | (5,6,7)    | (5,6,7)    | (3,5,33,7) | (3,5,33,7) | (5,6,7)    |
| CTS  | (3,4,33,6) | (3,4,5)    | (3,4,5)    | (3,4,33,6) | (3,4,5)    | (3,4,5)    | (3,4,5)    | (3,5,33,9) | (3,6,9)    | (3,5,33,9) | (3,5,33,9) | (3,5,33,9) |
| CSTC | (1,5,9)    | (2,6,33,9) | (1,6,9)    | (7,8,9)    | (7,8,9)    | (7,8,9)    | (7,8,9)    | (2,6,33,9) | (2,5,9)    | (2,6,33,9) | (2,6,33,9) | (2,6,33,9) |
| KED  | (1,3,67,7) | (2,3,4)    | (2,3,4)    | (2,3,4)    | (2,3,4)    | (2,3,4)    | (2,3,4)    | (2,5,9)    | (2,5,9)    | (2,5,9)    | (3,6,9)    | (2,5,9)    |
| FEP  | (2,3,67,5) | (3,4,5)    | (3,4,5)    | (3,5,8)    | (3,4,5)    | (3,4,5)    | (3,4,5)    | (2,3,67,5) | (2,3,67,5) | (2,3,67,5) | (2,3,67,5) | (2,3,67,5) |
| RI   | (2,5,33,9) | (3,5,33,9) | (3,5,33,9) | (3,5,33,9) | (3,5,33,9) | (3,5,33,9) | (3,5,33,9) | (3,4,5)    | (3,4,67,7) | (3,4,5)    | (3,4,5)    | (3,4,5)    |

Table 6 consists of six rows and twelve columns where columns are intellect errors and the rows consist of solutions for these twelve mentioned intellect errors. The aggregated fuzzy matrix is the result of 15 experts

who have rated six solutions concerning twelve intellect errors using linguistic scale. Aggregated fuzzy matrix is calculated using equation 8.

**Table 7: Normalized Fuzzy Evaluation Matrix for Intellect Solutions**

|    | EC       | EP       | SE       | Elg      | EH       | GE       | EB       | FE       | SubE     | AE       | Elr      | EM       |
|----|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| IF | (0.14,0. | (0.14,0. | (0.14,0. | (0.14,0. | (0.14,0. | (0.11,0. | (0.14,0. | (0.14,0. | (0.14,0. | (0.14,0. | (0.14,0. | (0.14,0. |
| L  | 25,1.00) | 17,0.20) | 17,0.20) | 25,0.50) | 19,0.33) | 19,1.00) | 17,0.20) | 17,0.20) | 17,0.20) | 19,0.33) | 19,0.33) | 17,0.20) |
| CT | (0.17,0. | (0.20,0. | (0.20,0. | (0.17,0. | (0.20,0. | (0.20,0. | (0.20,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. |
| S  | 23,0.33) | 25,0.33) | 25,0.33) | 23,0.33) | 25,0.33) | 25,0.33) | 25,0.33) | 19,0.33) | 17,0.33) | 19,0.33) | 19,0.33) | 19,0.33) |
| CS | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. |
| TC | 20,1.00) | 16,0.50) | 17,1.00) | 13,0.14) | 13,0.14) | 13,0.14) | 13,0.14) | 16,0.50) | 20,0.50) | 16,0.50) | 16,0.50) | 16,0.50) |
| KE | (0.14,0. | (0.25,0. | (0.25,0. | (0.25,0. | (0.25,0. | (0.25,0. | (0.25,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. |
| D  | 27,1.00) | 33,0.50) | 33,0.50) | 33,0.50) | 33,0.50) | 33,0.50) | 33,0.50) | 20,0.50) | 20,0.50) | 20,0.50) | 17,0.33) | 20,0.50) |
| FE | (0.20,0. | (0.20,0. | (0.20,0. | (0.13,0. | (0.20,0. | (0.20,0. | (0.20,0. | (0.20,0. | (0.20,0. | (0.20,0. | (0.20,0. | (0.20,0. |
| P  | 27,0.50) | 25,0.33) | 25,0.33) | 20,0.33) | 25,0.33) | 25,0.33) | 25,0.33) | 27,0.50) | 27,0.50) | 27,0.50) | 27,0.50) | 27,0.50) |
| RI | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.11,0. | (0.20,0. | (0.14,0. | (0.20,0. | (0.20,0. | (0.20,0. |
|    | 19,0.50) | 19,0.33) | 19,0.33) | 19,0.33) | 19,0.33) | 19,0.33) | 19,0.33) | 25,0.33) | 21,0.33) | 25,0.33) | 25,0.33) | 25,0.33) |

For comparing all the criteria, linear transformation of all the raw data is necessary so that data is normalized. Equation 15 will be used to generate the normalized data of Table 7.

$$R = [\tilde{r}_{ij}]_{s \times t} \quad i = 1, 2, \dots, s, \quad j = 1, 2, \dots, t \quad (15) \text{ where}$$

$$\tilde{r}_{ij} = \left( \frac{d_{ij}}{f_j^*}, \frac{e_{ij}}{f_j^*}, \frac{f_{ij}}{f_j^*} \right) \text{ where } f_j^* = \max_i \{f_{ij}\} \text{ (Benefit Criteria)}$$

$$\tilde{r}_{ij} = \left( \frac{f_j^-}{d_{ij}}, \frac{f_j^-}{e_{ij}}, \frac{f_j^-}{f_{ij}} \right) \text{ where } d_j^- = \min_i \{d_{ij}\} \text{ (Cost Criteria)}$$

**Table 8: Weighted Fuzzy Evaluation Matrix for Intellect Solutions**

|    | EC       | EP       | SE       | Elg      | EH       | GE       | EB       | FE       | SubE     | AE       | Elr      | EM       |
|----|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| IF | (0.01,0. | (0.02,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.02,0. | (0.01,0. | (0.01,0. |
| L  | 02,0.09) | 02,0.02) | 01,0.01) | 02,0.04) | 01,0.02) | 02,0.10) | 02,0.02) | 01,0.02) | 02,0.02) | 02,0.04) | 01,0.01) | 01,0.01) |
| CT | (0.01,0. | (0.02,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.02,0. | (0.02,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. |
| S  | 02,0.03) | 03,0.04) | 01,0.01) | 02,0.03) | 02,0.02) | 02,0.03) | 03,0.03) | 02,0.03) | 02,0.03) | 02,0.04) | 01,0.01) | 01,0.02) |
| CS | (0.01,0. | (0.01,0. | (0.00,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. |
| TC | 02,0.09) | 02,0.06) | 01,0.04) | 01,0.01) | 01,0.01) | 01,0.01) | 01,0.01) | 01,0.04) | 02,0.05) | 02,0.06) | 01,0.02) | 01,0.03) |
| KE | (0.02,0. | (0.02,0. | (0.01,0. | (0.02,0. | (0.02,0. | (0.02,0. | (0.03,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. |
| D  | 02,0.04) | 03,0.04) | 01,0.01) | 03,0.04) | 02,0.03) | 03,0.05) | 03,0.05) | 02,0.04) | 02,0.05) | 02,0.06) | 01,0.01) | 01,0.03) |
| FE | (0.01,0. | (0.01,0. | (0.00,0. | (0.01,0. | (0.01,0. | (0.02,0. | (0.02,0. | (0.02,0. | (0.02,0. | (0.02,0. | (0.01,0. | (0.01,0. |
| P  | 02,0.04) | 02,0.04) | 01,0.01) | 02,0.03) | 02,0.02) | 02,0.03) | 03,0.03) | 02,0.04) | 03,0.05) | 03,0.06) | 01,0.02) | 01,0.03) |
| RI | (0.01,0. | (0.01,0. | (0.00,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.01,0. | (0.02,0. | (0.01,0. | (0.02,0. | (0.01,0. | (0.01,0. |
|    | 02,0.04) | 02,0.04) | 01,0.01) | 02,0.03) | 01,0.02) | 02,0.03) | 02,0.03) | 02,0.03) | 02,0.03) | 03,0.04) | 01,0.01) | 01,0.02) |

**Table 9: Ranking of Intellect Solutions**

| Solutions | Fi+      | Fi-        | CCi         | Rank |
|-----------|----------|------------|-------------|------|
| IFL       | 0.277075 | 11.758629  | 0.976978931 | 3    |
| CTS       | 0.249336 | 11.762863  | 0.979243071 | 1    |
| CSTC      | 0.282709 | >11.766406 | 0.976536975 | 4    |
| KED       | 0.368640 | 11.669540  | 0.969377437 | 6    |
| FEP       | 0.304394 | 11.711677  | 0.974667741 | 5    |
| RI        | 0.249853 | 11.767752  | 0.979209389 | 2    |

Table 8 is required to calculate the weights of solutions by using equation 9. It is a pre-step before evaluating the ranking of solutions. This is one of the steps for the integration of fuzzy AHP and fuzzy TOPSIS. Table 9 is constructed using equation 14 and it is calculated after figuring out the rank order simultaneously for the fuzzy positive ideal solution and fuzzy negative ideal solution.

## 5. Conclusion

This study proposes a structured multi-criteria decision-making hybrid approach for evaluating and

selecting the best teaching solution to minimize intellect errors. The strength of the proposed hybrid approach is to manage the experts' judgments precisely and carefully. Firstly, intellect errors and their solutions are identified from the literature. This is the neglected aspect of teaching and their literature is not explored vastly in the past. A total of twelve intellect errors and six solutions have been identified. Secondly, fuzzy AHP is applied to intellect errors to compute the weights. The intellect errors are ranked using fuzzy AHP as EP > AE > EB > SubE > GE > EC > FE > Elg > EH > EM > Elr > SE. The most committed error by the intellects is 'error of

proximity' (EP) followed by analogy error (AE). The least committed error is 'senses error' (SE). Thirdly, these computed weights of fuzzy AHP are used in fuzzy TOPSIS to rank the teaching solutions that help in minimizing the intellect errors so that the learning capabilities of students are enhanced. Then, fuzzy TOPSIS ranked the solutions as CTS > RI > IFL > CSTC > FEP > KED. The topmost solution is 'development of critical thinking in the students' and the least one is 'knowledge engineering developments'. This study reports that only curriculum updating is not the way to make students ready for industry. The students can be made industry-ready with the student-teacher attributes. These ranked solutions can act as a guideline for teachers to make students industry-ready. In the future, different multi-criteria techniques can be used like fuzzy ANP, fuzzy ISM, and fuzzy ELECTRE to rank teaching solutions and the results will be compared with the current methodology.

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#### Annexure A: Intellect Errors with Abbreviations

| Intellect Errors       | Abbreviations |
|------------------------|---------------|
| Error of coincidence   | EC            |
| Error of proximity     | EP            |
| Senses error           | SE            |
| Error of ignorance     | Elg           |
| Error of habit         | EH            |
| Generalization error   | GE            |
| Error of the bandwagon | EB            |
| Familiarity Error      | FE            |
| Subjectivity Error     | SubE          |
| Analogy Error          | AE            |
| Error of irrelevance   | Elr           |
| Error of the machine   | EM            |

#### Annexure B: Intellect Errors Solutions with Abbreviations

| Solutions                                                               | Abbreviations |
|-------------------------------------------------------------------------|---------------|
| Teachers should be innovative, flexible and learners                    | IFL           |
| Development of critical thinking skills in the students                 | CTS           |
| Intellects should have good communication skills and team collaborators | CSTC          |
| Intellects should be aware of knowledge engineering developments        | KED           |
| Follow ethical practices                                                | FEP           |
| Selection of right instruments for teaching                             | RI            |

# The Factors Driving Career Planning and Mentoring in Four Year UG Engineering Education using ML Techniques

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**Abstract:** Career Planning is a continuous process of evaluating individual career goals through self-assessment, market research and objectively meeting the goals through continuous learning. In the context of Industry 4.0, career planning is not just limited to working professionals, but also plays a major role for the professional engineering students. Mentoring becomes a solid supporting prop to reach these goals systematically. It requires a philosophy, proper design of methodology, and organization structure. This study explores various factors driving career planning and mentoring in Four year UG Engineering Education. In this context, authors conducted literature survey and student's survey on 171 students to understand various factors, skill levels needed in designing career planning model and proposed mentoring model using Machine Learning Techniques (k-Means Clustering Algorithm). Further, authors surveyed 1525 students to understand career aspirations, designed Center for Career Planning organization and experimenting this model in a leading private group engineering college.

**Keywords:** Career Planning; Under Graduation Student Career Options; Skills for Engineering Students; Mentoring; Machine Learning.

## 1. Introduction

Career Planning provides a direction, identifies the strengths and weaknesses, skills and knowledge, in order to achieve the career goals. According to Schermerhorn et al.,(2005), "Career planning is a process of systematically matching career goals and individual capabilities with opportunities for their fulfilment". Career planning includes two important phases- Assessment (aspirations and skills) and Development (analysing the opportunities and alignment to the opportunities). This process would be successful when there is an action plan and periodic reviews. This is where mentoring plays a major role. In conjunction with proper mentoring, career planning creates a profound impact in reaching the career goals. Contradictory to the popular perception, Career Planning is not just applicable to employees, but it also important for UG Engineering students. The under graduate curriculum is adopting internships, job oriented skill training programs, electives, multi-disciplinary courses, campus recruitment programs, etc. Hence, it is important to identify various factors driving career planning and mentoring in UG professional courses.

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This paper is structured as follows. Section 2 discusses the literature survey. Section 3 presents the methodology and results for factors driving career planning. Section 4 presents the proposed clustering model for UG Engineering Students. Section 5 presents the threats to validity. Section 6 presents the conclusion

## 2. Literature Survey

In this section, we present the literature survey conducted in order to identify factors driving career planning. The best and perfect career choice plays major role in student's life (Alberts et al., 2003). This step ensures better employability and job satisfaction in long term (Jainani, 2018). Career is an application of a person's cognition and capabilities and provides basis for developing business networks (Redman and Wilkinson, 2001).

Career planning is the process to pursue his/her growth objectives in conformity with his/her expertise in the area, capabilities and aims (Bayraktaroğlu, 2011). Career choice is influenced by 2 factors- social factors (family, environment, social bonds, etc.) and psychological factors (perception, cognitive intentions, beliefs, ideas, personality and assessments, etc.) (Özen, 2011).

Career should improve standard of living, cultural environment, his family experiences, guidance and expectation provided and pertinent to particular field (Cavus et al., 2015) and (Muraguri, 2011). Another study states that Employment opportunities and learning experiences have major influence (Edwards and Quinter, 2012). According to Hewitt, few intrinsic reasons like passion, parent's choice, social prestige, job opportunities, income factors play major role in career planning (Hewitt, 2010). Influential people may play an important role for selection of any career path among youth (Wildman et al., 2001). Academic performance also plays major role in career planning (Schermerhorn et al., 2005). Dominant family business influences the career choice esp. in selecting particular field (Fizer, 2013). According to Perrone et al., (2001), "There is a difference between the choice of male and female in selecting the career choice".

A research was conducted to investigate the factors that influence the career choice in UG and PG Business students. The most influencing factor is "interest in the subject", which has direct linkage with

personality type. This study also proposes the importance of student counselling sessions and other interventions to improve the results. Career choice is partially influenced by social class, financial resources, affordability and future employability" (Ahmed et al., 2017) and (Kerka, 2000).

## 3. Methodology and Results

In this section, we present the methodology adopted and results of the survey process. Based on the literature survey and expert opinions (industry, academia, recruiters and parents), we identified important factors of the career planning and mentoring.

We have adopted the survey method of quantitative research by designing a structured instrument (questionnaire) which was to be answered by the UG students, chosen from different backgrounds and geographical locations. Total number of participants are 175 students across various Engineering Colleges.

### 3.1 Survey Results

Student's segmentation involves dividing a student base into groups of individuals based on certain traits they share. We divided survey questions into following four types of segmentation models.

1. Demographic Segmentation Model: Gender, Year of Study, Parent's Income Group, Sibling's Position, Department,
2. Geographical Segmentation Model: State, Current Stay (Hostel/Day Scholar)
3. Psychographic Segmentation Model: Goals, Constraints Level to pursue goals, Commitment Level, Working in Social Projects, Natural Skills, Type of person (Creative, Leader, Follower, Context Dependent), Personality Qualities
4. Technographic Segmentation Model: Academic Performance, Group Discussion Performance, IT Skills Readiness, Domain Readiness, Communication (Oral and Written), Presentation Skills, Prototype Making Skills, Business Pitch Skills, Aptitude, Technical Projects, Mentor Availability.

The following section presents survey results & analysis.

### 1. Gender Analysis:

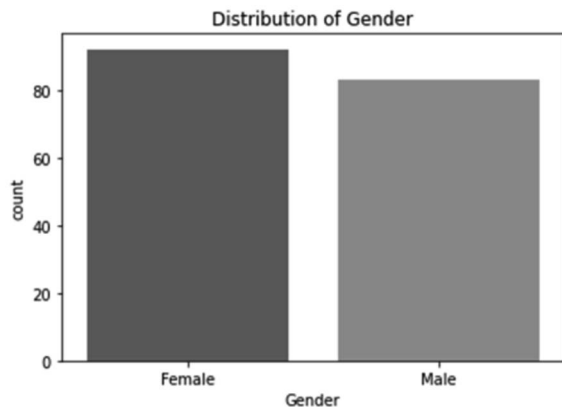


**Fig. 1: Male vs. Female**

As part of the survey, male and female ratio (48% and 52%) is almost equal, which brings un-bias in the decisions.

### 2. Year Wise Student's Participation

Further, we analysed year wise student's participation by gender.

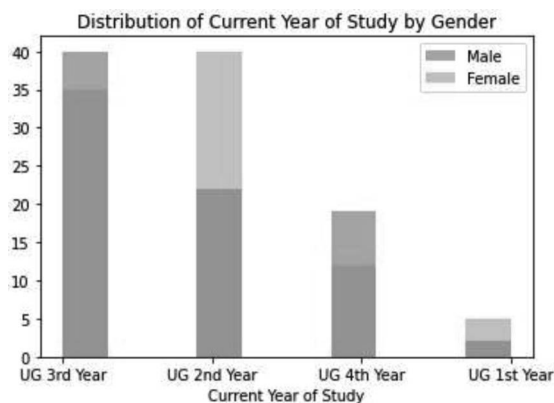


**Fig. 2 : Year wise Student's Participation by Gender**

We have 43% participation from UG 3rd Year, 35% from UG 2nd Year, 16% from UG 4th Year, 5% from UG 1st Year with almost equal gender ratio. This kind of participation shows the maturity of the students who are ready to plan their career (majority participants are from 3rd and 2nd Year).

### 3. Location



**Fig.3 : Student Location**

Majority of the participants are from Andhra Pradesh (91%) and Telangana Regions (8%).

### 4. Parents Occupational Position

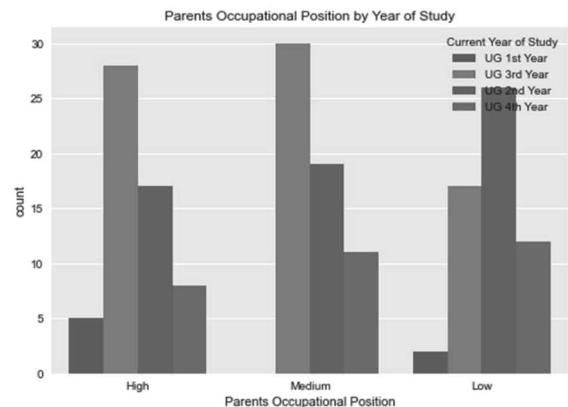


**Fig.4: Parent's Occupational Position by Year of Study**

We categorized survey participants into three groups (High, Medium, and Low) based on their parent's occupational position. We surveyed parent's occupation and made a heuristic approach in the categorization. We observed that majority of the participants belong to Medium and High class families.

We observed more male participants are from financially constrained families as showed in Fig.5.

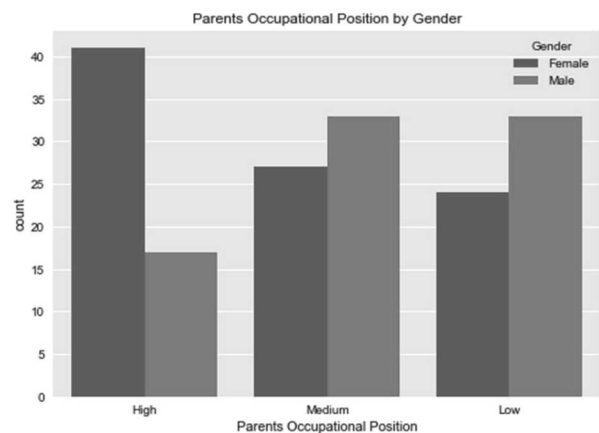


**Fig. 5 : Parent's Occupational Position by Gender**

### 5. Siblings Support / Occupation

We understand that ordinal position of siblings, age spacing, and gender composition has huge impact in terms of identity development as well as career development in traditional family setting. It is also studied that there are variations of parenting across sibling's birth order. In order to study this, we collected sibling's occupational or current status as showed in Fig. 6. Many participants are having

student siblings. This promotes competitive spirit in the home environment but less of sibling mentoring support.

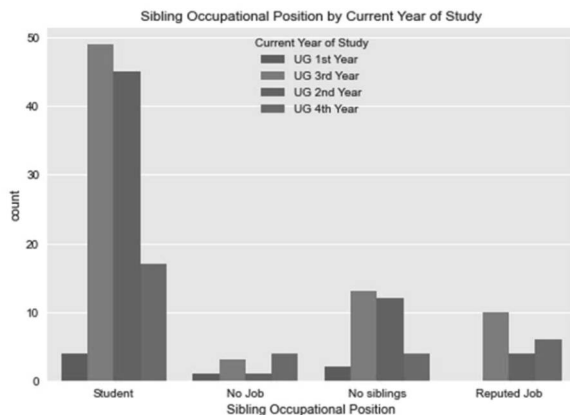


**Fig.6: Sibling's Occupational Position by Year of Study**

Female participants are having more student siblings than male as shown in Fig. 7.



**Fig. 7. Sibling's Occupational Position by Gender**

## 6. College Type

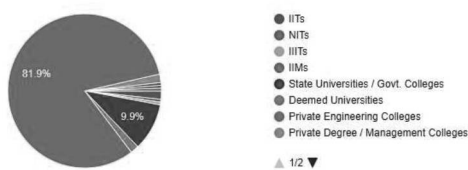


**Fig. 8. College Type**

Majority of the participants are from Private Engineering Colleges with 82%, Govt. State Engineering Colleges (10%), Deemed Universities (2%), IITs (2%), NITs (1%).

## 7. Stay during College

We observed that 58% students are day scholars

and 37% are hostellers. This becomes good distributed sample for finding career influences.

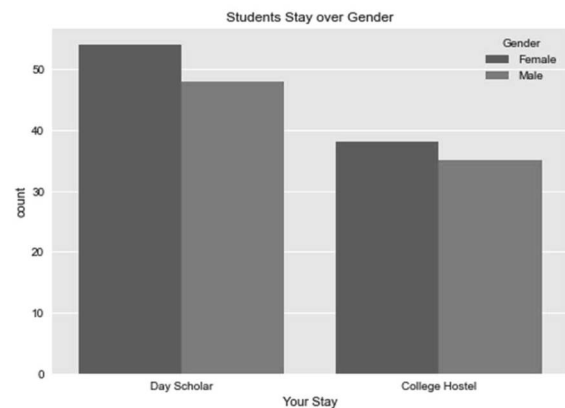


**Fig.9: Stay during Education**

We also observed that there is no significant difference between genders over stay preference. This signifies the equal opportunity.

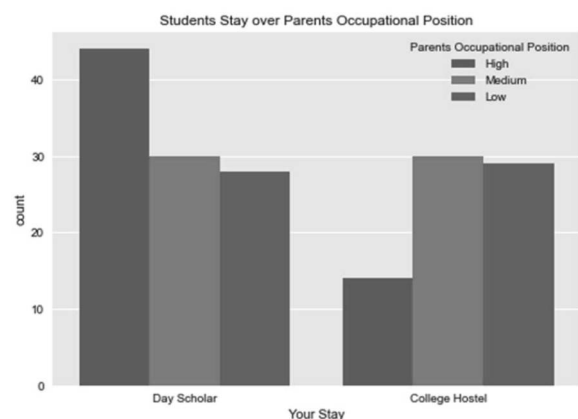


**Fig.10: Stay during Education**

It is observed that more number of day scholars with high & medium parental financial position

## 8. Engineering Branch

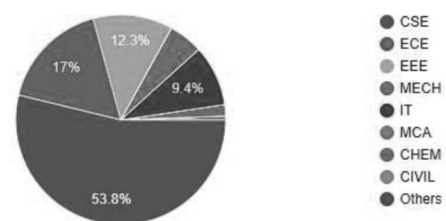


**Fig. 11 : Engineering Branch**

% are from CSE, 17% are from ECE, 12% from EEE, 5% from Mech, 10% from IT and others 2%. It is reflecting current market preference.

## 9. Student Goals

We requested participants to select goals. 44% opted GATE/Core Engineering, 14% Opted GRE, 11% opted for Civil Services/Competitive, 21% opted for IT/Software Jobs, 4% for CAT/GMAT / Management, 5% to start their own start up, and 1% for creative jobs. UG Engineering students have exhibited mixed aspirations contrary to engineering allied jobs only.

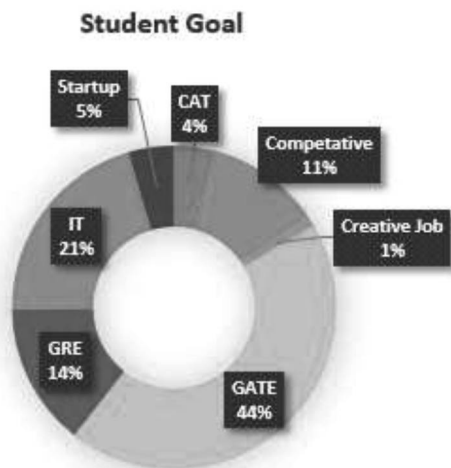


Fig. 11: Proffered Goals

The aspirations are having influence over parent's occupational position. Students from varied backgrounds are having different type of goals. Lower financial background students are aspiring more of competitive exams than upper financial background as shown in Fig.12. This is quite understandable that lower financial background students look for better stability and low risk options. Upper financial background students aspired more for GRE than middle and lower background students. Middle class background students are aspiring more for IT jobs.

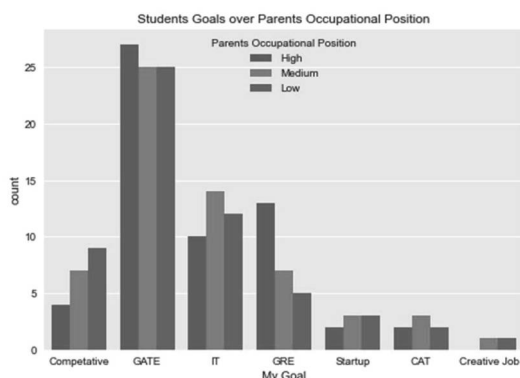


Fig. 12 : Proffered Goals over Parents Position

## 10. Financial and Social Constraints

63% of participants mentioned, "I have financial/social constraints but still want to pursue my interest at any cost". 35% mentioned, "I don't have financial/social constraints but intact with goals". It shows that most of the students wish to fulfil their goals in spite of their background.

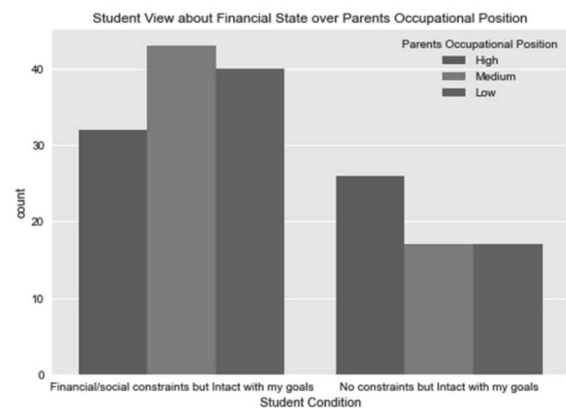


Fig. 13 : Financial and Social Constraints over Parent's Occupational Position

We corroborated this data with parent's occupational position. The data is matching as shown in Fig.13.

## 11. Academic Performance

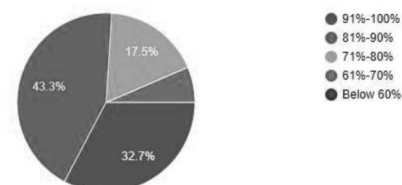


Fig. 14 : Academic Performance (+12 to UG)

This sample presents that most of the participants are academically serious.

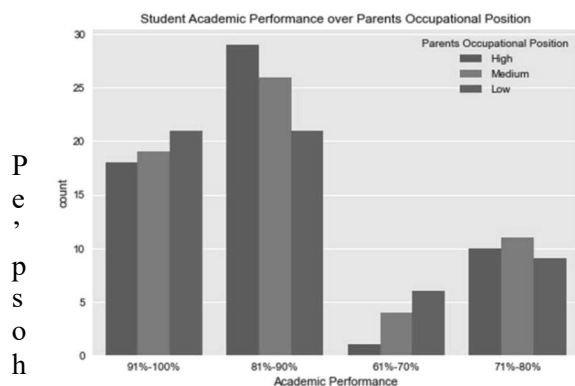


Fig.15 : Academic Performance over Parent's Position

major bearing on overall academic performance. However, the students from lower and middle class background fared high in 91%-100% bracket as shown in Fig.15.

Similarly, Gender has no major significance in overall academic performance except in 91%-100% bracket where girls outperformed boys as shown Fig.16.

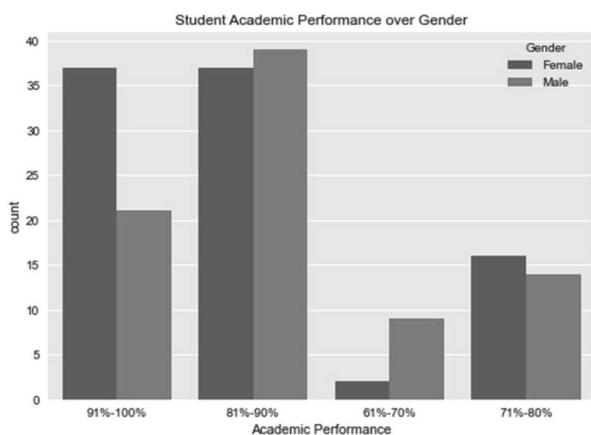


**Fig.16: Academic Performance over Gender**

## 12.Commitment

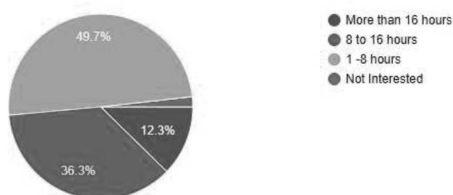


**Fig. 17 : Time Commitment**

50% of the participants are committed to keep 1-8 hours (outside the college hours) towards their goal. 36% committed for 8-16 hours outside the college hours. 12% committed for keeping more than 16 hours outside the college hours. This sample exhibited to keep extra effort towards their goals.

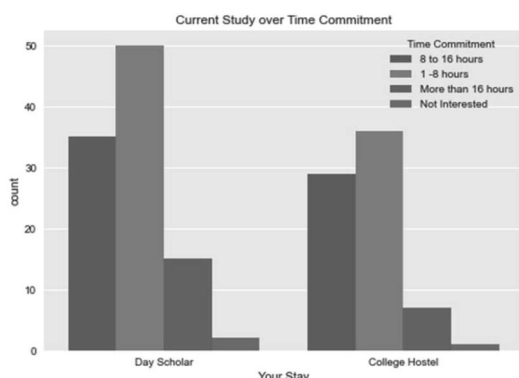


**Fig. 18 : Student Stay over Time Commitment**

mitted for extra hours to pursue the goals as shown Fig.18.

## 13.IT Technologies Readiness

93% of the sample mentioned that they have basic programming knowledge. 4% of the participants mentioned that they have competitive coding knowledge. 2% of them having animation knowledge and 1% mentioned that they do not have any IT exposure. This sample depicts the familiarity with IT skills. Third year students are highly familiar with IT systems.

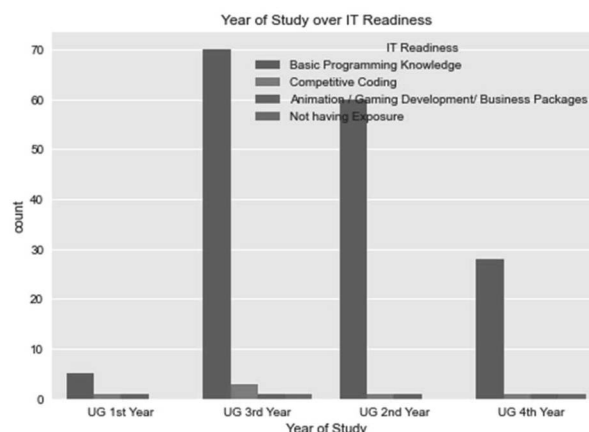


**Fig. 19 : IT Readiness**

## 14.Domain/ Subject Readiness

We surveyed Subject or Domain Readiness (e.g. Knowledge in e-commerce, retail, HR, Finance, Engineering -Manufacturing Process, Energy, Agriculture, Healthcare, Chemical, Supply chain, Instrumentation, Civil Engineering, Economics, etc.). 67% are having college level basic understanding of their subject. Only 33% participants are confident at expert level.

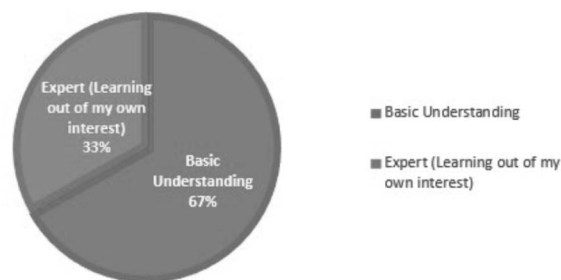


**Fig. 20 : Domain / Subject Readiness**

## 15. Communication Skills (Oral)

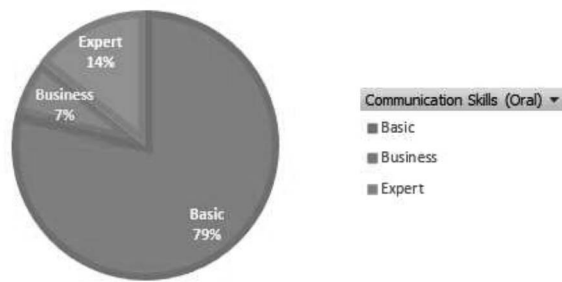


Fig. 21 : Communication Skills (Oral)

79% of the students are having basic oral communication. 14% are having expert level communication. 7% are having business communication skills.

## 16. Communication Skills (Written)

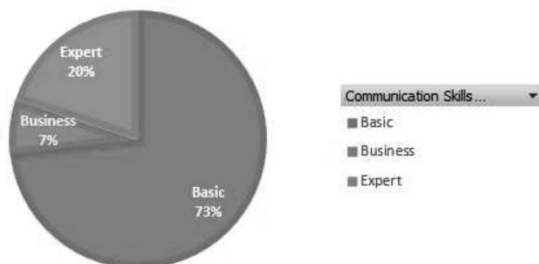


Fig. 22 : Communication Skills (Written)

73% of the participants are having basic written communication. 20% are having expert level written communication. 7% are having business written communication skills.

## 17. Presentation Skills

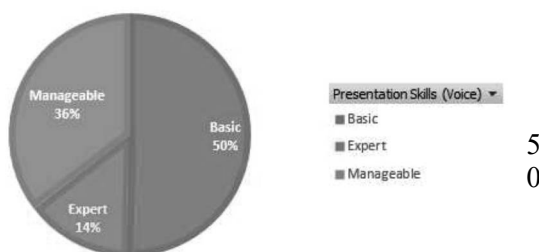


Fig. 23 : Presentation Skills

% of the students are holding basic presentation skills, 36% are with manageable level and 14% with expert level.

## 18. Report / Article Preparation Skills



Fig. 24 : Report / Article Preparation Skills

46% of the sample holds basic preparation skills, 32% manageable, and 22% with expert level.

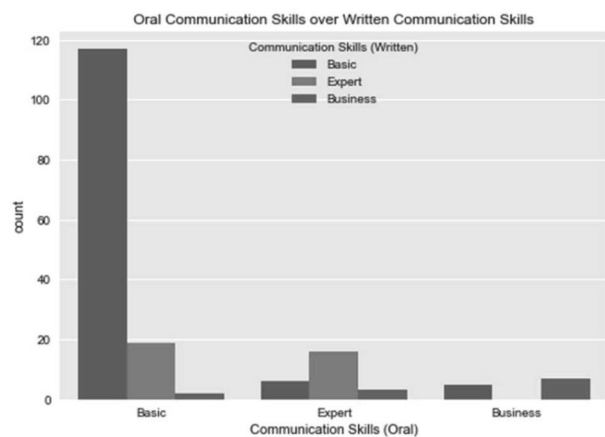


Fig. 25: Communication Skills Oral over Written Skills

We observed that majority of the sample possess basic level oral & written communication skills as shown in Fig.25.

## 19. Prototype or Model Making Skills

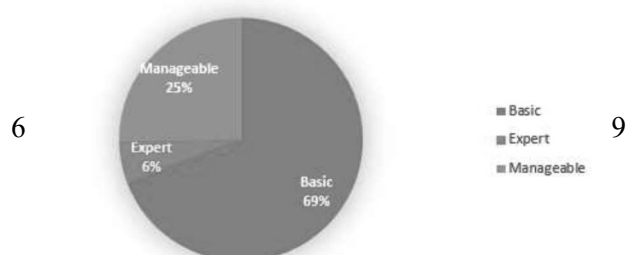


Fig. 26 : Prototype or Model Making Skills

% of the students are having basic prototype making skill, 25% of them at manageable level and 7% with expert level. This shows that many students are lagging on model making skills.

## 20. Participation in Business Pitch Competitions



**Fig. 27 : Participation in Business Pitch Competitions**

We observed that 66% sample never participated in business pitch competitions. 24% participated once. 9% twice in the last 2 years. Participation in competitive challenges and business pitch competitions is highly critical for presentation and idea development skills. It helps in entrepreneurial career planning.

## 21. Level of Logical Reasoning and Aptitude in Competitive Exams (e.g. NTSE, Olympiad, KVPY, Competitive Exams)

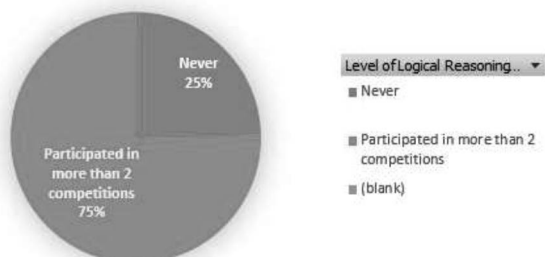


**Fig. 28: Participation in Competitive Exams**

75% participated more than twice in the last 2 years and 25% never participated. There is a need for better participation.

## 22. Working Experience in Social Projects

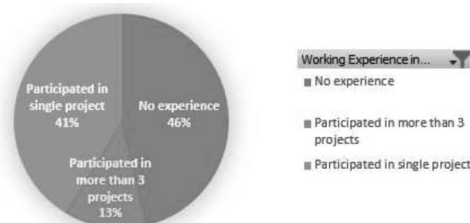


**Fig. 29 : Participation in Social Projects**

53% participated in single social project. 18% participated in three projects and 29% are not having

any experience. Participation in Social projects increases the level of problem identification, design thinking and solution development with respect to business viability, technical feasibility and human desirability.

## 23. Working Experience in Technical / Business Projects



41% participated in single project. 13% participated in more than 3 projects. 46% do not have any experience. Technical or business projects increase the awareness towards financial mapping, investments, usability, productivity etc.

Technical or business projects increase the awareness towards financial mapping, investments, usability, productivity etc.

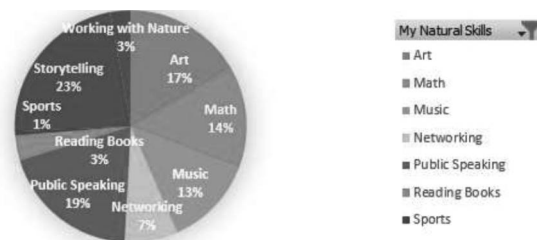


**Fig. 31: Student Natural Skills**

## 24. Natural Skills

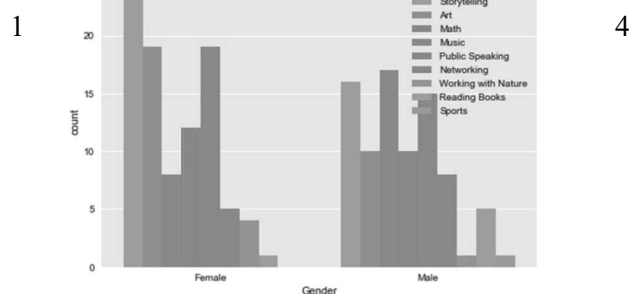


**Fig. 32 : Natural Intelligence over Gender**

% claimed Math or Logic skills, 23% with storytelling, 19% public speaking, 17% Art, 13% Music, 7% Networking skills, 3% Naturalistic Intelligence, 3% with Book Reading, 1% with sports. This spread is completely varied. Each individual is born with certain intelligence. If this is included in the career-planning, job satisfaction is increased.

Female Participants claim more storytelling, art, public speaking compared to male participants. Male

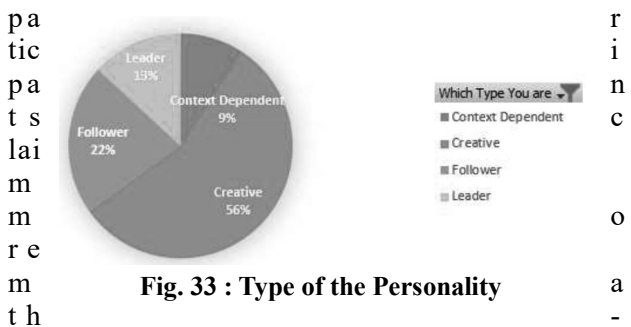


Fig. 33 : Type of the Personality

logic intelligence compared their female counterparts as shown in Fig.32.

25. Which type are you?

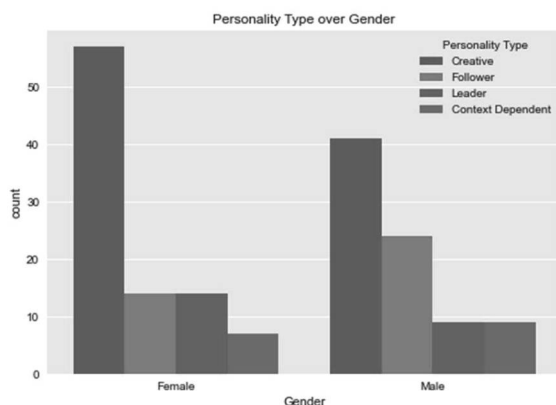


Fig. 34 : Type of the Personality over Gender

56% of the participants claimed of creative type, 13% of them are of leadership type, 22% of them are follower type, 9% are of context dependent type. Sample is perfectly mixed with all type of



Fig. 35 : Quality Description

Female participants are more of creative type compared to male counterparts.

26. Which quality (s) describes me

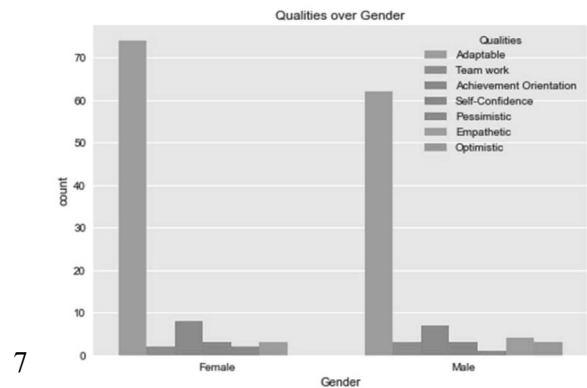


Fig. 36 : Quality Description over Gender

% of participants claimed adaptable to situation, 8%

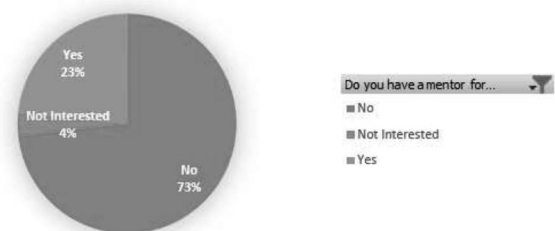


Fig. 37 : Mentor Availability

achievement orientation, 2% empathetic, 2% optimistic life, 2% pessimistic, 3% self-confident, and 3% teamwork. This sample has completely mixed portfolio. Both genders claim similar qualities as shown in Fig.36

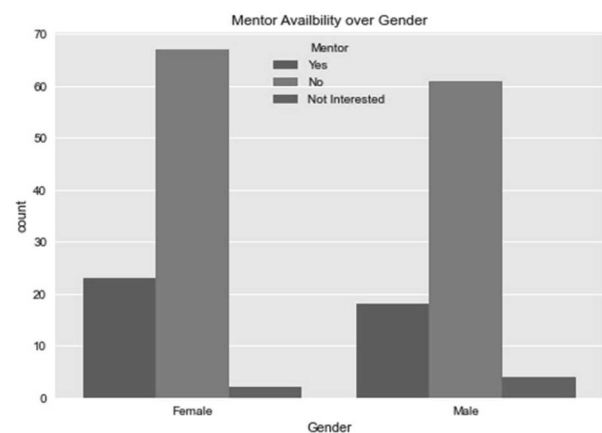


Fig. 38 : Mentor Availability over Gender

## 27. Mentor Availability

73% of them do not have mentor for their career planning and development. This situation demands the need for mentoring and counselling. Both female and male are in a similar composition in terms of lack of mentor for their career planning.

## 3.2 Mentoring through Clustering Methods

The term mentoring means that the support given by the more experienced person for the growth and learning of another. As per the Smith (2007) “a particular mode of learning wherein the mentor not only supports the mentee, but also challenges them productively so that progress is made”. According to Cox (2005), Mentors, in the traditional sense of the term, are usually people in leadership roles or are people whom the mentee aspires to be like.

| Variable                                              | Observations | Minimum | Maximum | Mean  | Std. devia |
|-------------------------------------------------------|--------------|---------|---------|-------|------------|
| Which one of the following situations describes you   | 168          | 1.000   | 5.000   | 3.048 | 1.443      |
| Your Average Academic Performance (+2 to till date)   | 168          | 2.000   | 5.000   | 4.042 | 0.871      |
| How many hours you would like to spend per week       | 168          | 1.000   | 5.000   | 3.583 | 0.777      |
| I have an opportunity to participate in a formal Gro  | 168          | 1.000   | 5.000   | 2.887 | 1.599      |
| My IT Readiness( Skill set that I possess)            | 168          | 1.000   | 5.000   | 2.571 | 1.596      |
| My Subject or Domain Readiness (e.g. Knowledge in     | 168          | 1.000   | 5.000   | 3.571 | 1.119      |
| Communication Skills (Oral)                           | 168          | 1.000   | 5.000   | 1.750 | 1.430      |
| Communication Skills (Written)                        | 168          | 1.000   | 5.000   | 1.976 | 1.608      |
| Presentation Skills (Voice)                           | 168          | 1.000   | 5.000   | 2.369 | 1.454      |
| Article / Report / Presentation Making (using ppt /   | 168          | 1.000   | 5.000   | 2.524 | 1.582      |
| Prototype or Model Making Skills                      | 168          | 1.000   | 5.000   | 1.714 | 1.164      |
| Did you participate in an Idea presentation or 3 pitc | 168          | 1.000   | 5.000   | 1.446 | 0.756      |
| Level of Logical Reasoning and Aptitude in Competi    | 168          | 1.000   | 5.000   | 3.048 | 1.434      |
| Working Experience in Social Projects                 | 168          | 0.000   | 5.000   | 1.482 | 1.153      |
| Working Experience in Technical / 3 Projects          | 168          | 0.000   | 5.000   | 1.315 | 0.942      |

Fig. 39 : Summary Statistics

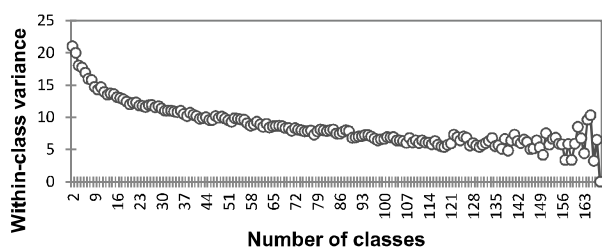


Fig. 40 : Evolution of Variances

| Iteration | Within-class variance | Trace(W) | ln(Determinant(W)) | Wilks' Lambda |
|-----------|-----------------------|----------|--------------------|---------------|
| 0         | 25.203                | 4133.225 | 79.924             | 0.743         |
| 1         | 20.255                | 3321.833 | 77.777             | 0.087         |
| 2         | 19.008                | 3117.362 | 77.456             | 0.063         |
| 3         | 18.423                | 3021.443 | 76.997             | 0.040         |
| 4         | 18.058                | 2961.554 | 76.625             | 0.027         |
| 5         | 18.037                | 2958.147 | 76.584             | 0.026         |

Fig. 41 : Statistics for Each Iteration

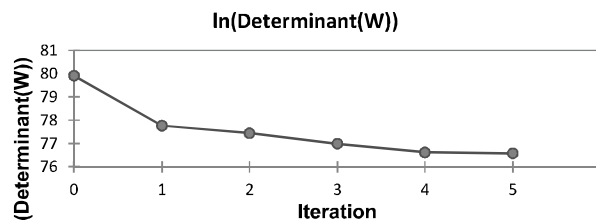


Fig. 42 : In Determinant (W)

|                 | Absolute | Percent |
|-----------------|----------|---------|
| Within-class    | 18.022   | 71.38%  |
| Between-classes | 7.226    | 28.62%  |
| Total           | 25.248   | 100.00% |

Fig. 43 : Variance decomposition for the optimal classification

|   | 1     | 2     | 3     | 4     |
|---|-------|-------|-------|-------|
| 1 | 0     | 3.597 | 5.327 | 4.089 |
| 2 | 3.597 | 0     | 5.278 | 3.059 |
| 3 | 5.327 | 5.278 | 0     | 5.707 |
| 4 | 4.089 | 3.059 | 5.707 | 0     |

Fig. 44 : Distances between the class centroids

A study was made on the importance of Mentoring. The students appreciated the role played by mentors. It is observed that mentor helped mentee in terms of feedback. The mentor acts as a change agent,

Table 1 : Results By Class

| Class                        | 1     | 2    | 3    | 4    |
|------------------------------|-------|------|------|------|
| Objects                      | 34    | 60   | 38   | 36   |
| Sum of weights               | 34    | 60   | 38   | 36   |
| Within-class variance        | 17.6  | 14.6 | 26.7 | 14.8 |
| Minimum distance to centroid | 2.04  | 1.7  | 3.2  | 1.9  |
| Average distance to centroid | 4.003 | 3.7  | 5.01 | 3.7  |
| Maximum distance to centroid | 7.1   | 5.4  | 6.9  | 5.8  |

collaborates, and helps through cognitive coaching. The aspect of change refers not only to the classroom practice but also to the development of an overall professional culture (Mpofu and Chimhenga, 2016).

Before assigning mentor, we need to cluster similar students so that instruction becomes more effective.

We used k-Means Clustering Algorithm to cluster the participants (Xiaoliang et al., 2020). We made 4 clusters as showed below.

k-means clustering (Number of classes = 4):

As showed in Table 1, Class 1 has 34 Participants, Class 2 has Participants, Class 3 has 38 Participants, Class 4 has 36 Participants.

This method is useful to create like-minded groups.

#### 4. Proposed Clustering Model for UG Engineering

Further, authors propose following organization structure using clustering model for career planning.

This is designed after multiple interviews with Industry personnel, academicians, students over a period of 3 years.

| Heads-On           |                 |                       | Hands-On         |              |                 | Hearts-On                              |                                   |                                |
|--------------------|-----------------|-----------------------|------------------|--------------|-----------------|----------------------------------------|-----------------------------------|--------------------------------|
| Engineering Domain |                 |                       | Finishing School |              |                 | Management-Innovation-Entrepreneurship |                                   |                                |
| GATE<br>ESE        | Core<br>Company | GRE<br>TOEFL<br>IELTS | IT               | ITES/<br>KPO | Non-<br>IT/MSME | CAT<br>GMAT                            | CIVILS /<br>Competiti<br>ve Exams | Startup/<br>Family<br>Business |

**Fig. 45 : Student Career Aspiration vis-v-vis Wish-Fulfilment Plan**

Second Year UG Engineering is the right time for making the career plan. It is observed that if a student takes any career decision in the First Year, it is called as “Patriotic Decision” as the decision carries a lot of emotions. If student takes any career decision in the Third Year, it is called as “Pricking Decision” as student has less time to plan and prepare. If student takes any career decision in the Fourth Year, it is called as “Paralytic Decision” as student has no time to plan and prepare. Hence, if student takes any career decision in the Second Year, it is called as “Perfect Decision” as student gets sufficient time to plan and prepare.

Based on the student's wish, Intellectual Quotient, Emotional Quotient, and Social Quotient levels, the following model can be executed.

Industry 4.0 is threatening traditional job systems, skills and educational needs. It is compelling huge change in education institutions in the form of Education 4.0. Education 4.0 complaint institutions are expected to have administrators, teachers, trainers,

researchers, counsellors, mentors, advisors and inspirers. Job is not limited to knowledge sharing but also to inspire the student, give an opportunity to set a goal, identify the skill needs and meticulously plan for fulfilment of the student's wish.

Progressive institutions, proactively setting up Centre for Career Planning which cater to the needs of students with diversified background. Few may be having high intelligent quotient, few good emotional quotient, few good social quotient, few with creativity and business acumen. This composition is varied in every student. Each student is designed for certain job. Institutions have to honour and respect this kind of intelligence composition. Each student is having different aspirations. Mentors need to map both aspects meticulously and mentor students accordingly. Mentor's job is to identify the student competencies and intelligence composition, collect aspirations and make a customized plan for every student and facilitate the same. This is huge new age strategic and operational requirement.

Broadly, Institutional level Centre for Career Planning should have 3 verticals- Heads On, Hands On and Hearts On. Each vertical is critical in its function, role in the society and providing equal opportunity to all types of students.

1. “Heads On Vertical” caters to the needs of GATE, ESE, CORE JOB and GRE where deep theoretical engineering understanding or research orientation is required.
2. “Hands On Vertical” works towards needs of IT, ITES, KPO, RPO Opportunities where it caters to the needs of programming skills, domain skills, language skills and other Finishing School skills
3. “Hearts On Vertical” broadly caters to the needs of CAT/GMAT, Civil Services and Other Competitive Examinations, Start-up and Family

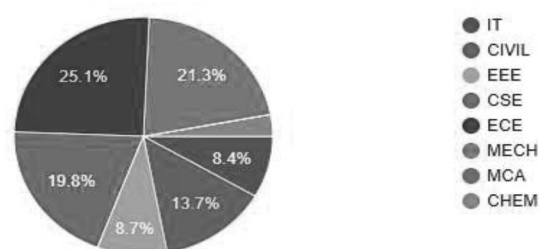


**Fig. 46 : Dept. wise Student Career Aspirations**

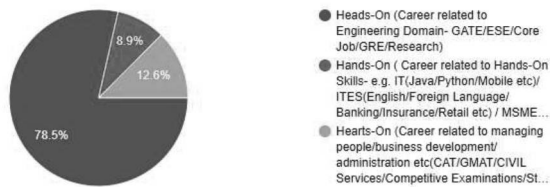


**Fig. 47 : Heads On vs. Hands On vs. Hearts On**

Business Opportunities where individual requires leadership capabilities, managing teams, managing risks, financial management, business execution capabilities etc.

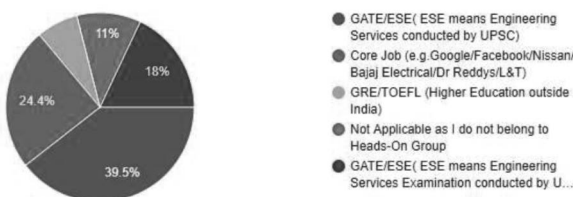


**Fig. 48 : Heads On (GATE vs. Core Job vs. GRE)**

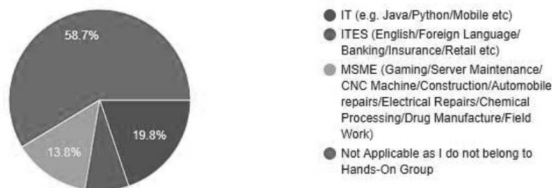


**Fig. 49 : Hands On (IT vs. ITES vs. MSME Type)**

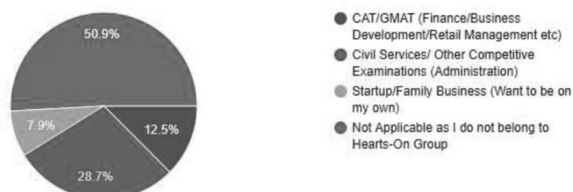


**Fig. 50: Hearts On(CAT vs. Civil Services Vs.Start-up)**

#### 4.1 Pilot & Methodology

Based on this model, it is experimented in the one of the leading private engineering group colleges. Students were given orientation towards Heads On, Hands On and Hearts On options. A survey has been conducted for all students of second year to state their personal career choice and vertical which they would like to be attached to. Students completed this survey on their own, in free & fair fashion. Students shared

constructive suggestions to support this process. A total of 1525 students participated in this survey across 4 group colleges. Survey Period- Oct 2018.

It is observed that more than 78% opted for Hands On vertical. The following Figures 48, 49, and 50 details further break up of Heads On, Hands On and Hearts On.

#### 4.2 Interventions and Impact

After clustering students according to these verticals, mentors were assigned to students. Institution has roped in training partners to provide external guidance and training. This model is in operation for more than 2 years. Students are getting mentored to full-fill their career wish. More than 12 start-ups were incubated so far. More than 15 student patents were published. Students are trained for GATE and mentored by experts. More than 60% students already got placed in various IT companies. Civil Services training is getting imparted to more than 60 students. More than 50 students are getting trained in CAT.

#### 5. Threats to Validity

While designing this model, we attempted to survey students from one region. It is desired to increase the sample size across multiple regions so that feasibility accuracy can be improved. Mentoring is 4 years process in UG Engineering Education. This kind of projects need lot of time to measure the impact. Proper results can be published only after ascertaining results from few outgoing batches.

#### 6. Conclusions

A large portion of our life is spent in achieving career goals. A well-designed career plan is important which provides a roadmap for the student's future. It helps in multiple means. Student gets an opportunity to leverage strengths, develop confidence, and helps to invest time and skills in a way that is emotionally satisfying. Self-assessment plays major role in career planning. Mentoring helps to improve the leadership skills, opportunity to learn from the mentors, and finally improves the student's chance for success. Mentoring through clustering methods create like-minded groups. This creates peer-learning environment. While segmenting students, it is important to consider demographic, geographical, psychographic and Technographic aspects. However,

assigning right mentor at right time is a herculean task for large institutions where student population is huge with diversified aspirations, level of absorption and skills in the limited 3-year window. Machine learning techniques like k-Means clustering algorithm can help to cluster the similar set of students. This process helps in making instruction effective. Clustering survey questions should be customized according to year of study and type of need. The number of clusters can be determined based on the availability of mentors and quality of mentoring. In this survey, institution is a tier-2 type with medium student population size. Hence, number of clusters (4 in this case) is sufficient. However, in large University cases, we should go with more number of clusters. Proactively, progressive institutions should set up Centre for Career Planning, adopt mentor-training programs and mentor students according to intelligent, emotional, and social quotients.

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# Computational Solvers for Iterative Hydraulic loss Calculations in Pipe Systems

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**Abstract** —The study of fluid mechanics spans several engineering disciplines including Mechanical, Civil, Aerospace, Chemical, Environmental, Petroleum, and Biomedical Engineering. In all these disciplines, hydraulic loss calculations in pipes are extremely important. However, the iterative nature of the solution to these engineering problems makes it intricate and cumbersome to solve. Further, it gets very difficult to visualize the solutions to such iterative problems for a wide variety of cases. The current paper aims to bridge this gap by the creation of two open-source Excel-VBA based computational solvers. The first tool corresponds to the determination of the Darcy-Weisbach friction factor through the Colebrook Equation and its visualization on a Moody's chart, which can be effectively employed by engineering instructors as an active learning tool. Second, a complete tool covering all four kinds of pipe flow situations (including the iterative problems) has been developed. The developed computational tools were employed in an

undergraduate Fluid Mechanics classroom and the detailed student responses were collected on ten aspects related to teaching and learning divided broadly under four categories – 'overall rating', 'student perceptions on self-learning', 'Improvement in teaching delivery', and 'recommendation for other courses'. The data collected from student responses were subjected to statistical analysis. The results of hypothesis testing and the p-value calculations clearly justify the immense usefulness of this tool in the improvement of the overall teaching-learning process of Fluid Mechanics. Finally, the developed computational tools are being hosted free on the web for the benefit of engineering instructors, learners and professionals alike.

**Keywords:** Pipe losses; computational tool; Fluid Mechanics; Hydraulic loss; Moody's chart; Excel VBA.

## 1. Introduction

Engineering applications pertaining to fluid flows are frequently encountered by engineers of several disciplines, such as mechanical, civil, aerospace, chemical, petroleum, environmental or biomedical engineering (Appanaboyina and Aung, 2004). For instance, the design and operation of water distribution networks in urban sewage systems., the heat exchanger piping system designs and the prediction of pumping power requirements, the flow

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regulation inside pipelines in the chemical industry, the transportation of crude petroleum in the long pipelines, the design of hydraulic lines in an aircraft, or even the biomedical equipment design such as syringe needles, pumps for various applications as well as Lab on a chip, etc. are some relevant problems that require an in-depth knowledge of fluids in general, and hydraulic losses in particular (Türkkan et al., 2020).

Understanding the principles of pipe flow and fluid flow and applying these principles to industrial and engineering applications, however, is a challenge for undergraduate and postgraduate students for the following reasons: the subject involves the usage of highly advanced mathematics topics such as tensor calculus, vector, and partial differential equations. Solutions to these problems are generally obtained by sophisticated experiments and complicated computations that are difficult to understand. The design of pipelines require a consideration of materials, the diameter of the pipe, length of the pipe, friction factor, and other parameters. The knowledge of pressure drop in a pipe and other piping systems dimensions are of much importance from the viewpoint of pump selection. The pressure drop in a pipe can be easily calculated using the well-known Darcy-Weisbach equation and in such a scenario, parameter calculations are optimum in the sense that the calculated parameters are those required to exactly meet the stated specifications (Boulos and Wood, 1990). However, given a pressure drop, the calculations of diameter/length of pipe and discharge are difficult owing to the requirement of repetitive calculations.

It is particularly in problems such as the pipe flow calculations, the traditional teaching methods fall far short of the mark in communicating the complex design procedures. Further, the students can't explore the cause and effect of property magnitude changes in such an engineering scenario. More so, resorting only to the conventional pen-and-paper methodology of solving such challenging engineering problems is not only cumbersome but also reveals a clear disjoint between the concurrent industrial practice and the engineering pedagogy. Evidently, there is a need for a suitable technological intervention to bridge this gap and to enable students to see the integration of computers in engineering and its practical utility in solving challenging engineering assignments. It is expected that such computational schemes such as simulation/ visualization tools may help students

easily assimilate the concepts, gain the hidden insights and thus stimulate them to explore themselves, facilitating 'self-learning'.

As far as computational frameworks are concerned, there are a variety of software/ computer languages, both commercial and open-source which can be amicably employed in the solution of pipe flow problems and the visualization of the data involved, such as:

- Python
- Scilab
- Matlab
- Wolfram Mathematica
- Pyro
- Cycle Pad, etc.

In fact, there are many computational fluid dynamics (CFD) software packages available in the market, although its practical utility for an average undergraduate student of fluid mechanics is limited. This is because of multiple reasons including the high cost of the software, the requirement of high-configuration computers, and also the steep learning curve typically required to do any meaningful analysis with these software (Appanaboyina and Aung, 2004). Hence, MS Excel / VBA platform was selected for the development of a computational solver because of its user-friendly nature, low cost, and easy availability. Excel VBA helps an engineering learner to solve critical equations, scale live graphs, to learn new concepts just by changing the parameters without worrying about the errors. It can be equally utilized to stage unique engineering demonstrations and animations. The programming language of VBA allows the user to access functions beyond what is available in other Microsoft applications (Mahawar et al., 2020). Users can use the application of VBA to customize applications according to the need, such as creating user-defined functions, etc. Moreover, owing to its very user-friendly nature, a simple interface and a wide variety of specifications, it can also be used to create computerized tools (El-Bahrawy, 1997).

Considering the user-friendly nature of Excel/VBA, it helps to solve critical equations, scale live graphs, to learn new concepts just by changing the

parameters without worrying about the errors. For the calculation of pipe flow parameters, two Excel workbook programs have been designed that allows the user to calculate parameters as per the requirements. While the first tool deals with the determination of friction factor using Moody's chart, the second tool consists of four types of pipe flow problems, where three parameters are known and the fourth parameter can be solved for. The paper continues with the description of the spreadsheet, some sample problems solved using the VBA tool. Finally, this tool was utilized for teaching and learning in an undergraduate Fluid Mechanics classroom and the student responses have been collected in the form of an online survey. The results have been collated and statistical analysis have been conducted to gauge the effectiveness of such a computational tool on the overall teaching-learning process.

## 2. Background

For a one-dimensional flow in a pipe/duct, the energy conservation equation yields that the total energy head must remain a constant, commonly referred to as the Bernoulli equation. Bernoulli equation however ignores the viscosity present in the fluid. Upon taking the viscosity of the fluid into account, the total energy head does not remain constant along the pipe length. The total energy head is given by,  $H = z + \frac{P}{\rho g} + \frac{v^2}{2g}$ , where  $z$  is the elevation of the pipe,  $P$  is the fluid pressure,  $v$  denotes the average fluid velocity,  $\rho$  represents the density of the fluid, and  $g$  denotes the acceleration due to gravity. The total head,  $H$  decreases consistently along the pipe length due to the hydraulic losses ( $h_L$ ) caused by fluid viscosity. The hydraulic loss between two different cross-sections at points 1 and 2 along the pipe is given by the difference in total heads at the two points

$$h_L = H_1 - H_2$$

With the total head being calculated at points 1 and 2, engineering design for fluid motion in pipes and other closed conduits requires that head loss be expressed as a function of the fluid, its velocity, the pipe diameter, and pipe material (Brown, 2003). Such an expression to calculate energy losses is given by the Darcy-Weisbach equation:

$$h_L = f \frac{L}{D} \frac{v^2}{2g}$$

Where,  $v$  denotes the fluid velocity and  $L$  and  $D$  represent the length and the diameter of the pipe, respectively. Another term  $f$  represents friction factor, which is a function of Reynolds number and relative roughness,  $f = \phi(Re, \epsilon/D)$  and typically determined from Moody diagram (Moody, 1944) or other correlations (Colebrook et al., 1939), (Haaland, 1983) or (Swamee and Jain, 1976).

It is not easy to determine the functional dependence of friction factor on the Reynolds number and relative roughness, and much of the information present is a result of experiments conducted by many researchers since 1933. Combining all the data for transition and turbulent flows for smooth as well as rough conditions, Colebrook came up with the following relation known as the Colebrook Equation (Kudela, 2012) where  $\epsilon$  is the pipe roughness (in mm) and  $Re$  denotes Reynolds number given as  $Re = \frac{\rho v D}{\mu} = \frac{4Q}{\pi D \nu}$ ,  $\rho$ ,  $\mu$  and  $\nu$  denote fluid density, dynamic viscosity and kinematic viscosity, respectively.

$$\frac{1}{\sqrt{f}} = -2.0 \log \left[ \frac{2.51}{Re \sqrt{f}} + \frac{\epsilon/D}{3.7} \right]$$

It is worth pointing out that despite few explicit correlations for both friction factor and pipe flow problems proposed by researchers in the past, even to date, the Darcy-Weisbach equation combined with the Moody diagram/ Colebrook equation is the accepted and most accurate method for calculating the energy losses that occurs in pipe due to the fluid motion, as taught in the undergraduate Fluid mechanics curriculum. When these equations are used with continuity, energy and minor loss equations, can be used for analyzing and designing the pipe systems for any fluid. In other words, above equations can tell us the capacity of oil pipeline, diameter of pipe to install or the pressure drop in the system (Brown, 2003).

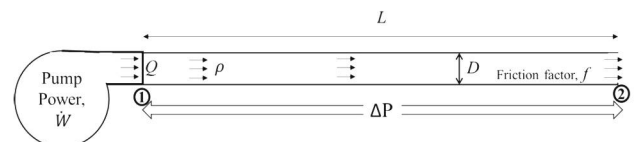


**Fig. 1 : A Schematic view of the straight pipe system showing key parameters involved in engineering design.**

Figure 1 presents a schematic view of the straight pipe system showing key parameters involved in its engineering design such as pump power requirement

W', discharge  $Q$ , density of fluid  $\rho$ , friction factor of the pipe,  $f$ , the geometrical parameters of the pipe such as  $L$  and  $D$  and finally, the pressure drop between two points 1 and 2. Typically, four kinds of problems are encountered in the design of such straight pipe systems. The first type (Type-I) of pipe flow problems usually entail the pressure drop calculations between two points at a distance  $L$  apart with  $D$  and  $Q$  being known. Type-II problems entail the determination of pipe length,  $L$  for a given  $\Delta P, Q$  and  $D$ . In Type-III problem, the computation of discharge is important for a given  $\Delta P, Q$  and  $D$ . Finally, in Type-IV the selection of pipe diameter  $D$  is to be done for a known  $\Delta P, Q$ , and  $L$ . In all these types of pipe problems, the fundamental equation for pressure drop as given by Darcy-Weisbach is to be utilized along with a suitable way of determining friction factor,  $f$ . The friction factor can either be determined by the Moody chart or the implicit Colebrook equation. For fully developed flows in full pipes, the friction factor is a dimensionless index of the pressure drop and its correct estimation is crucial for the design of these pipes (Calomino et al., 2015). However, apart from the problems involved in solving the implicit Colebrook equation, there is another factor that should be taken into account. In Type-I and Type-II problems, given the pipe diameter,  $Re$  can be easily computed for a given fluid, and if the pipe roughness is known,  $f$  can easily be estimated from both Moody chart or by solving the implicit Colebrook equation. Subsequently, the pressure drop or length calculations could be made. However, such is not the case with Type-III and Type-IV problems, where the calculation of  $Re$  can't be done since either the velocity or the diameter of the pipe is not known. In the absence of the  $Re$  value, the determination of  $f$  by Moody diagram or by Colebrook equation is not possible. In addition, prior literature (White, 1994) has stated that the Moody Chart is only accurate to within 15%. Hence, it should suffice to say that the practical design of such an engineering problem is beset with many challenges which include iterative calculations, and conventional approaches to solving these problems involves many trials and tedious computations (Swamee and Jain, 1976). This may just imply that engineering instructors may not be able to train the graduate with such skillsets if they were to restrict themselves to pen-and-paper calculations. However, such design problems become extremely handy if computational interventions are suitably designed and implemented, and may facilitate engineering instructors to better equip their graduates with skills to solve such problems, to make effective classroom

demonstrations, to give the students a 'feel' of the actual design parameters as well as to equip them with the understanding of integration of computers in solving such engineering design challenges, a much required skillset for industry. Hence, the current study proposes two computational solvers for this purpose: first, a computerized Moody chart solver for the determination of  $f$ . And second, a comprehensive tool that analyzes all four kinds of pipe-flow problems. All the types of pipe-flow problems are supplemented with a sample problem, which demonstrates the efficacy of solving such challenging and cumbersome engineering design problems at the click of a button.

However, there is a minor caveat that warrants mention. These computational tools are in no way a 'replacement' for the pen-and-paper calculations which are a must to ensure student learning. These computational tools may serve as perfect instruments of 'self-learning' where students can explore the effect of parametric variations, and also validate their pen-and-paper calculations. The instructors may also use these for active learning demonstrations inside the classroom or tutorial sessions. Further, it is overtly expected that the usage of such tools will stimulate students to learn the Goal-Seek and other ways to solve such iterative engineering problems.

### 3. Description Of The Computational Solvers

As mentioned in the previous section, two distinct computational solvers have been developed on the

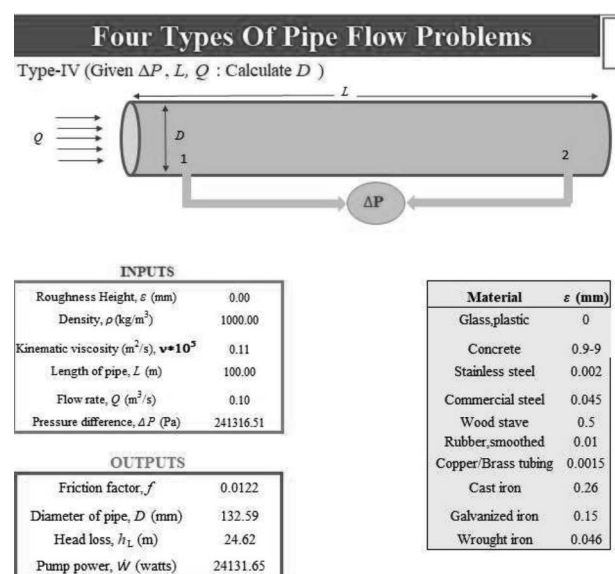


Fig 3 : Interface of pipe flow tool Solver as uploaded on the tools website <https://www.drkarnteaching.com/>

Excel VBA platform. The first one pertains to the computation of friction factor, and may be particularly relevant to the Type-I and Type-II fluid problems in pipe flows.

Figure 2 shows a schematic of the computerized Moody chart solver for the computation of the Darcy friction factor, which can be downloaded from <https://www.drkarnteaching.com/> by the engineering students, instructors, or professionals for the design of pipe flow systems. As the figure shows, the tool seeks three inputs : Reynolds number (Re), dimensional roughness height (in mm) and the diameter of the pipe. Reynolds number calculations for different fluids and at different temperatures can be easily obtained from the 'Fluid Property Calculator' tool by the authors from the same website. In addition, a table in the tool provides the range of roughness height for a variety of materials so that user may easily select and plug the right values in the inputs column. Upon feeding these desired inputs, the solver performs two tasks: first, it computes the Darcy friction factor value from the implicit Colebrook Equation and more importantly, it displays the same on a Moody diagram for visualization. Figure 2 demonstrates how the Moody diagram shows lines of different non-dimensional roughness in different colors, the regions of laminar, turbulent flow and a critical zone and a conspicuous red dot which shows the friction factor value for the chosen conditions. The tool does not merely compute the friction factor but also helps to visualize the regime of flow at the chosen conditions. This is of course, extremely helpful in providing a comprehensive parametric variation of the friction factor with Re in different regimes such as laminar flow or fully developed turbulent flows. Interestingly, a user can easily study parametric variations in the friction factor by tracing the location of the red dot marker, as the slider bar on Reynolds number is scrolled to the right, at a fixed pipe diameter providing for the effect of an increase in velocity alone. Conversely, a user can keep the Re fixed, and analyse the effect of increments in pipe diameter. In both the cases, it is interesting to note how the value of the friction factor 'jumps' during the transition from laminar to turbulent flows.

Next, Figure 3 presents the interface of the pipe flow solver. The computational tool comprises of four sheets, corresponding to four kinds of pipe flow problems. Each sheet offers its unique set of inputs and outputs, and also features a tabulation of the

roughness height for different materials, to aid the user in entering it. For instance, Figure 3 depicts the solution of a Type-IV pipe flow problem, which entails the determination of pipe diameter, given the pressure drop  $\Delta P$ , the length  $L$  of the pipe, and the discharge  $Q$ . Apart from these three inputs, the inputs table seeks fluid properties such as density and kinematic viscosity of the fluid and also the roughness height of the pipe. Subsequently, the tool calculates the corresponding value of friction factor  $f$ , pipe diameter  $D$ , required pump power and also the head loss in the process. For the purpose of verification, a sample problem from a textbook is also appended for each type of flow problem. Also, the basic equations used in the solutions of pipe flow problem are listed below (Demir et al., 2018):

$$\Delta P = \left(\frac{8}{\pi^2}\right) \rho f \left(\frac{L}{D^5}\right) Q^2$$

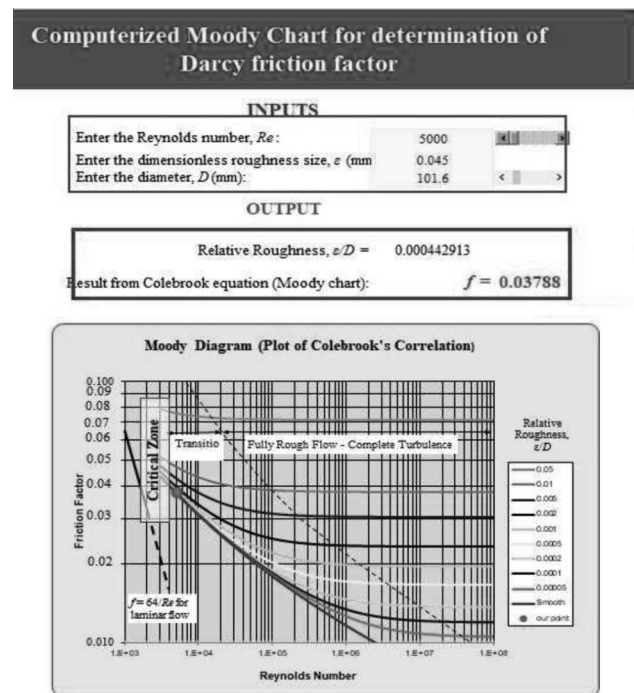


**Fig.2: Interface of Computerized Moody Chart Solver as uploaded on <https://www.drkarnteaching.com/>**

Where  $\Delta P$  is the pressure drop in a pipe,  $\rho$  is the density of the fluid,  $\epsilon$  is the roughness height of pipe,  $f$  is friction factor,  $L$  is the length of pipe,  $D$  is the diameter of the pipe and  $Q$  denotes the flow rate in a pipe. Pump power can be calculated by the given equation:

$$\text{Power, } \dot{W} = Q * \Delta P$$

Finally, the head loss can be calculated by the given equation:

$$\text{Head loss, } h_L = \frac{\Delta P}{\rho g}$$

Figure 4 demonstrates a flowchart depicting the typical algorithm behind the iterative solution of the Type-IV pipe problem. As the figure shows, the strategy begins with seeking the inputs from the user such as  $\Delta P$ ,  $L$  and  $Q$ , as well as the fluid properties and the roughness height. However, any solution for the pipe diameter from the Darcy-Weisbach equation can't proceed further without the friction factor. Paradoxically however, friction factor itself depends upon  $Re$  and relative roughness height, both of which depend upon the pipe diameter, Hence, the solution must proceed through an iterative scheme,

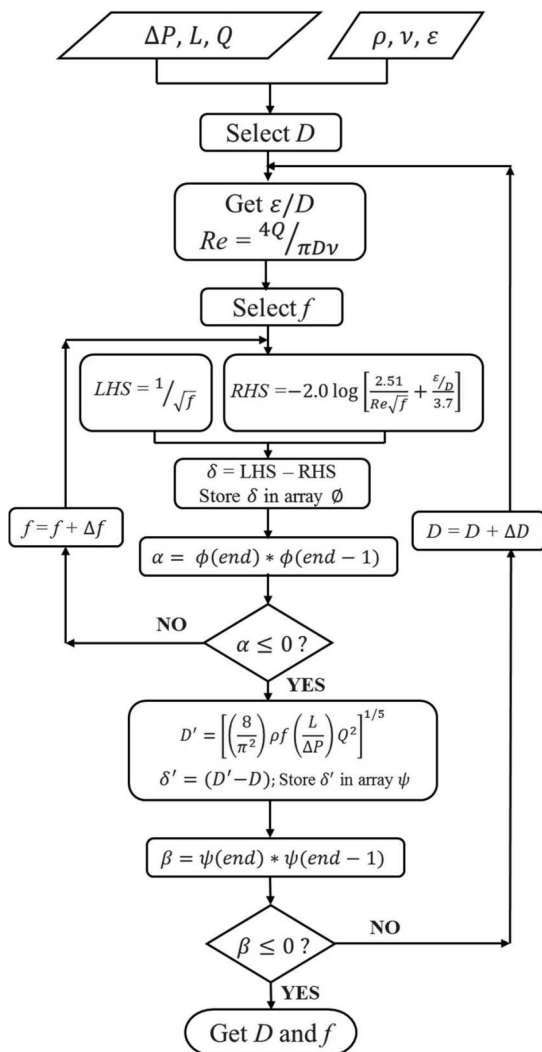


**Fig. 4 : Flowchart showing the algorithm behind computation of Type-IV pipe-flow problem. Note that**

commencing with the judicious selection of a pipe diameter. Theoretically speaking, the selection of a pipe diameter should suffice in enabling us to compute a value of the friction factor, if an explicit equation of friction factor were resorted to. However, to solve the implicit Colebrook equation, another set of repetitive and circular calculations for friction factor must be done. Hence, the calculation must proceed by the assumption of a suitable friction factor so that the LHS and RHS of the implicit Colebrook equation are determined and their difference,  $\delta$  (say,  $>0$ ) is determined and concatenated with an array  $\phi$ , which is initially a single-element vector containing a positive quantity (say,  $x$ ). During the first iteration, the product of  $\alpha = \phi(2) \phi(1)$  amounts to  $\delta x$ , which is a positive quantity. And hence, the iterations must continue with incremental changes in  $f$  till a non-positive value of  $\alpha$  is attained. Whenever this sign inversion of  $\alpha$  occurs, it is tantamount to saying that the curve intersects the abscissa and a root is obtained, or the most accurate solution of the implicit Colebrook equation is attained. Next, inserting this obtained value of  $f$  and other known parameters in the Darcy-Weisbach law, a new value of pipe diameter,  $D^{\wedge}$  can be calculated. The difference between the initially selected diameter and the calculated diameter,  $\delta^{\wedge}$  (again,  $>0$ ) is stored

```

Sub SOLVE6()
Range("BB6").GoalSeek GOAL:=0, ChangingCell:=Range("BB4")
Range("D") = Round(1000 * Range("BB4"), 2)
End Sub
  
```

**Fig. 5 : VBA code showing goal seek method**

inside another array  $\psi$  and the product of the last two elements of this array may be termed as  $\beta$ . The sign-inversion of  $\beta$  is a measure again of the accurate value of pipe diameter that satisfies all the given parameters.

Although the algorithm of this repeated iterative procedure may look somewhat involved, its actual implementation within the MS-Excel/VBA is rather quite straightforward and simple. In fact, its extremely user-friendly front graphical interface with a very simplistic backend coding in Visual Basic is one of those distinguishing features that makes it truly unique and attractive for developing applications that are easy to develop and use. Actually, this iterative and tedious computation can be very easily carried out in MS Excel with its 'GoalSeek feature'.

The Goal-Seek feature of MS Excel works on the principle of making a target cell reach an assigned value by the variation of a selected other parameter,

which is pre-assigned. For instance, in this Type-IV pipe-flow problem, the cell 'BB4' corresponds to the pipe diameter, whereas the cell 'BB6' is the target cell which pertains to the difference between LHS and RHS of the Colebrook equation, which is expected to reach a minimum value (close to zero), whereby the solution to this problem is said to be attained. Figure 5 indeed shows how the intricate algorithm can neatly and elegantly be expressed in few lines using the Goal-seek feature of MS-Excel.

Below, we produce four solved examples of the pipe flow problems of all four types for illustration, and to demonstrate the working and efficacy of the proposed computational tool.

#### 4. Solution Of Some Selected Problems

##### A. TYPE-I: Given L, Q, D - Calculate $\Delta P$

The following data is given for a pipe flow system as in Example 8.5 from Fox and McDonald's Introduction to Fluid Mechanics, page 372 (Pritchard and Mitchell, 2016):

A 100 m length of smooth horizontal pipe is attached to a large reservoir. A pump is attached to the end of the pipe to pump water into the reservoir at a volume flow rate 0.01 m<sup>3</sup>/s. What pressure (gage) must the pump produce at the pipe to generate this flow rate? The inside diameter of the smooth pipe is 75 mm.

Here, the user can calculate the pressure drop, knowing the other three parameters (length, diameter, and flow rate).  $\Delta P$  is calculated using the goal seek method in cell no BB4. Head loss has been calculated using the  $\Delta P$  value as shown in the given formula in Cell no J23.

$$J23 = \text{ROUND}(\text{del\_P}/(\rho \cdot 9.8), 2)$$

where cell no J23 refers to the value of the head loss. The power of the pump has been calculated using the given formula in cell no J24

$$J24 = \text{ROUND}(Q \cdot \text{del\_P}, 2)$$

where Cell no J24 refers to the pump power value.

Alternatively, friction factor can also be calculated using the computerized moody chart which can be used to calculate  $\Delta P$ . As Figure 6 shows, the values

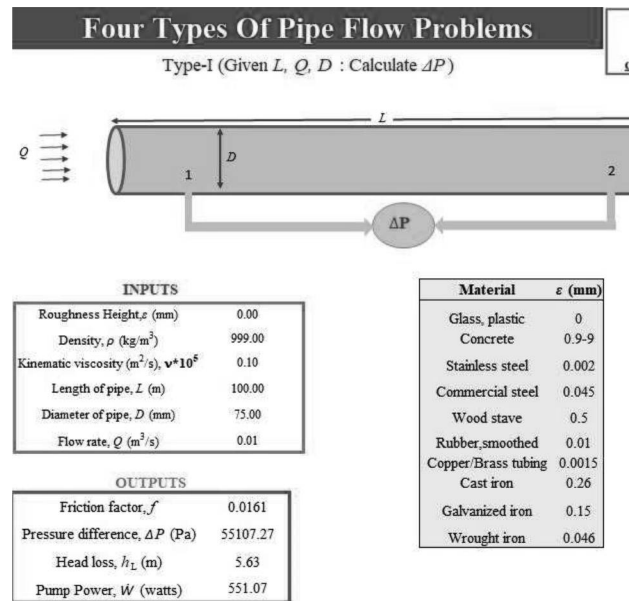


**Fig 6 : The solution to the Type-I flow problem from Fox and McDonald's Introduction to Fluid Mechanics, page 372 () using the developed computational tool.**

given in the problem, length=100 m, flow rate = 0.01 m<sup>3</sup>/s, diameter = 0.075 m (75 mm) are put in INPUT section of the tool, and it results in a friction factor value of 0.0161, pressure drop in the pipe as 55.11 kPa, a corresponding head loss of 5.63 m and the required pump power to be 551.07 watts. In reality, taking the mechanical efficiency of the pump into account, the pump power required may be slightly larger.

##### B. TYPE-II: Given $\Delta P$ , Q, D - Calculate L

The following data is given for a pipe flow system as in Example 8.6 from Fox and McDonald's Introduction to Fluid Mechanics, page 373 (Pritchard and Mitchell, 2016):

Crude oil flows through a level section of the Alaskan pipeline at a rate of 1.6 million barrels per day (1 barrel=42 gal). The pipe inside diameter is 48 in; it's roughness is equivalent to galvanized iron. The maximum allowable pressure is 1200 psi; the minimum pressure required to keep dissolved gases in solution in the crude oil is 50 psi. The crude oil has SG=0.93; its viscosity at the pumping temperature of 140°F is  $\mu=3.5 \times 10^{-4}$  lbf.s/ft<sup>2</sup>. For these conditions, determine the maximum possible spacing between pumping stations. If the pump efficiency is 85 percent, determine the power that must be supplied at each pumping station.

Here the user can calculate the Length of the pipe knowing the other three parameters (pressure drop, diameter and flow rate). Length of the pipe is calculated using the goal seek method in cell no BB4. Head loss and the required pump power has been calculated as described before in the first sample problem. Friction factor can also be calculated using the computerized moody chart which can be used to calculate  $L$ . As figure 7 shows, the values given in the problem, flow rate =  $1.6 \times 10^6$  barrels per day ( $2.94 \text{ m}^3/\text{s}$ ), diameter=48 inches ( $1.2192 \text{ m}$  or  $1219.20 \text{ mm}$ ), pressure difference =  $1150 \text{ psi}$  ( $7928970.89 \text{ Pa}$ ), density= $929.85 \text{ kg/m}^3$  are put in INPUT section of tool which results in friction factor value of  $0.0170$ , length of the pipe as  $192435.17 \text{ m}$ , a corresponding head loss of  $870.12 \text{ m}$  and the required pump power to be  $23344548.76 \text{ watts}$ . In reality, considering the mechanical efficiency of the pump, the pump power required may be slightly larger.

#### C. TYPE-III: Given $\Delta P, L, D$ - Calculate $Q$

The following data is given for a pipe flow system as in Example 8.7 from Fox and Mcdonald's Introduction to Fluid Mechanics, page 375 (Pritchard and Mitchell, 2016):

A fire protection system is supplied from a water tower and standpipe  $80 \text{ ft}$  tall. The longest pipe in the system is  $600 \text{ ft}$  and is made of cast iron  $20$  years old.

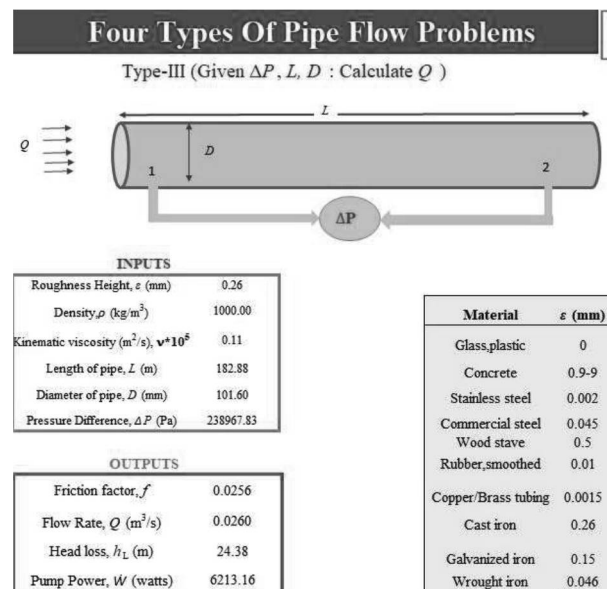


**Fig 8: The solution to the Type-III flow problem from Fox and Mcdonald's Introduction to Fluid Mechanics, page 375 () using the developed computational tool.**

The pipe contains one gate valve; other minor losses may be neglected. The pipe diameter is  $4 \text{ in}$ . Determine the maximum rate of flow (gpm) through this pipe.

Here the user can calculate the Flow rate knowing the other three parameters (pressure drop, diameter and length of the

pipe). Flow rate is calculated using the goal seek method in cell no BB4. Head loss and the required pump power has been calculated as described before in the first sample problem. As figure 8 shows, the values given in the problem, length= $600 \text{ ft}$  ( $182.88 \text{ m}$ ), diameter =  $4 \text{ inches}$  ( $0.1016 \text{ m}$  or  $101.60 \text{ mm}$ ), pressure difference of  $238967.83 \text{ Pa}$  are put in INPUT section of tool which results in friction factor value of  $0.0256$ , flow rate in pipe as  $0.0260 \text{ m}^3/\text{s}$ , a corresponding head loss value of  $24.38 \text{ m}$  and the required pump power to be  $6213.16 \text{ watts}$ .

#### D. TYPE-IV: Given $\Delta P, L, Q$ - Calculate $D$

The following data is given for a pipe flow system as in Example 8.8 from Fox and Mcdonald's Introduction to Fluid Mechanics, page 376 (Pritchard and Mitchell, 2016):

Spray heads in an agricultural spraying system are to be supplied with water through  $500 \text{ ft}$  of drawn

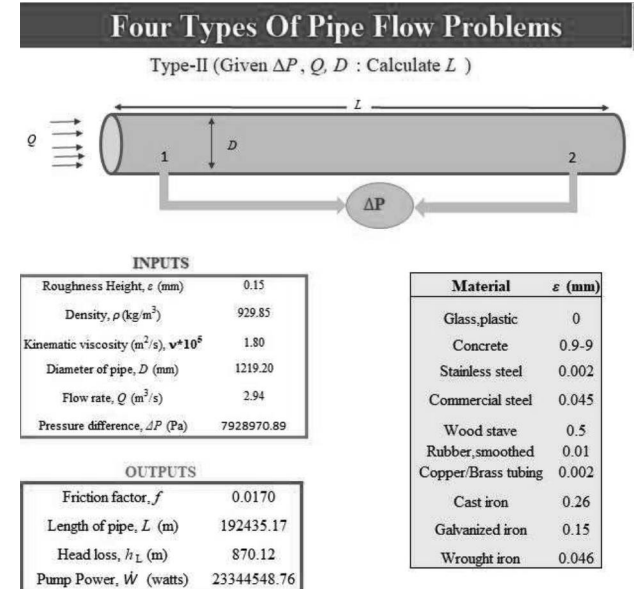


**Fig. 7 : The solution to the Type-II flow problem from Fox and Mcdonald's Introduction to Fluid Mechanics, page 373 (Pritchard and Mitchell, 2016) using the developed computational tool.**

aluminium tubing from an engine driven pump. In its most efficient operating range, the pump output is 1500 gpm at a discharge pressure not exceeding 65psig. For satisfactory operation, the sprinklers must operate at 30 psig or higher pressure. Minor losses and elevation changes may be neglected. Determine the smallest standard pipe size that can be used.

Here the user can calculate the diameter of the pipe knowing the other three parameters (pressure drop, flow rate and length of the pipe). Diameter of the pipe is calculated using the goal seek method in cell no BB4. Head loss and the required pump power has been calculated as described before in the first sample problem. As figure 9 shows, the values given in the problem, length=500 ft (152.40 m), flow rate=1500 gpm (0.09 m<sup>3</sup>/s), pressure difference = 35 psig (241316.51 Pa) are put in INPUT section of tool which results in friction factor value of 0.0124, diameter of pipe as 0.14161 m (141.61 mm), a corresponding head loss of 24.62 m and the required pump power to be 22837.06 watts.

## 5. Users Surveys And Hypothesis Testing

Finally, to test the efficacy of the developed computational tool in enhancing the teaching and learning of pipe flow problems in undergraduate Fluid mechanics course has been tested by taking sample surveys of a variety of users and the resulting data has been analysed using hypothesis testing principles, to arrive at some substantive conclusions. In order to collect the data, the developed tool was uploaded on the course website <https://www.drkarnteaching.com/fluid-mechanics-tools> or a blind review and it was given access to the second year B.Tech Mechanical Engineering, Mechatronics Engineering and Automotive Design Engineering students who have studied the Fluid Mechanics course. The tool was also open for review from the B.Tech third year students as well as the faculty/ research scholars who wished to provide the data and feedback for the innovative tool.

The feedback/ data collection form comprised of ten questions, and the users were expected to provide ratings for each of these questions from 1 to 5. In the quantitative part, 1 referred to a strong disagreement whereas 5 indicated the vice-versa, i.e. a strong endorsement. In addition, qualitative feedback was also sought from the participants regarding the different aspects of the computational tools as well as its overall usefulness and effectiveness. Table 1 enlists the ten questions the users of the tool were asked to

**Table 1 : Statement Of Survey Questions Given to the Users/ Different Alternative Hypotheses In Hypothesis Testing**

| #   | Hypothesis                                                                                                               |
|-----|--------------------------------------------------------------------------------------------------------------------------|
| 1.  | The developed computational tool considerably improves the overall teaching-learning experience of pipe flows.           |
| 2.  | This computational design tool inspires students to do quality work.                                                     |
| 3.  | The developed computational tool helps retain the interest and attention of the students in the Fluid mechanics subject. |
| 4.  | The strategy of employing computational tool helps in cooperative peer learning.                                         |
| 5.  | The difficulty level of the subject was considerably reduced with the help of this computational solver                  |
| 6.  | This teaching strategy will help students to see integration of computers in engineering education.                      |
| 7.  | This computational solver helps students significantly in applying theoretical concepts to real-life problems.           |
| 8.  | The Pipe flow interactive tool is a great lecture demonstration to aid students' understanding.                          |
| 9.  | The developed computational tool is helpful in honing problem solving skills during the tutorial sessions.               |
| 10. | Based on the benefits derived from this solver, such a computational tool is recommended for other courses.              |

respond to, apart from their qualitative remarks. A general description of the questions posed in the survey can thus be made: the first questions seeks the user input regarding the overall usefulness of this tool

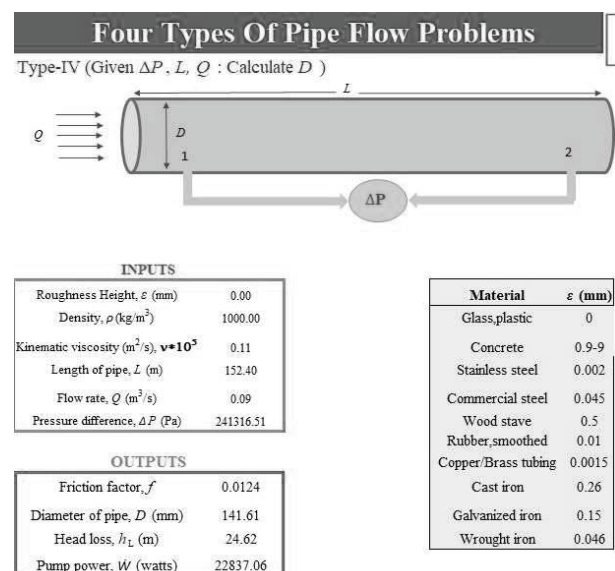


**Fig. 9 : The solution to the Type-IV flow problem from Fox and Mcdonald's Introduction to Fluid Mechanics, page 376 (Pritchard and Mitchell, 2016) using the developed computational tool.**

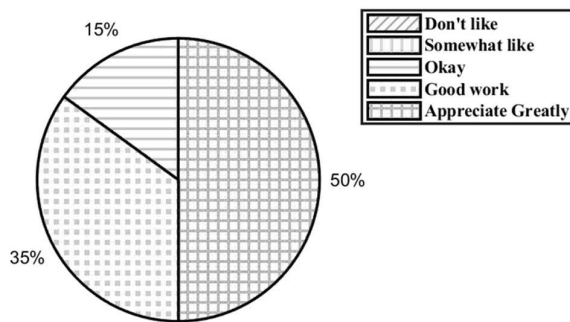


**Fig. 10 : User perceptions on overall improvement of the teaching-learning experience of pipe flows.**

in teaching and learning of pipe flows, whereas the last query specifically pertains to whether based on the benefit derived from such tools in the Fluid mechanics course, the students would like to see such a strategy being implemented in other engineering courses. The middle eight questions are further grouped under two heads: the first one relates specifically to the students' perceptions regarding aiding self-learning (question # 2-5) and includes difficulty reduction, creating opportunities for cooperative learning, sustaining their interest in the subject as well as assistance that such tools provide in doing quality work in engineering. The second group pertains to the instructor and instructional perspective, such as enabling students to see the computers in engineering professions, enabling students to teach real-life problems, facilitating lecture demonstration of crucial concepts, as well as aiding in the smooth conduction of tutorial sessions for the students. A total of twenty user responses were received. These users belonged to the different states of India.

#### A. Overall acceptance of new method

Figure 10 displays a pie chart of the user perceptions regarding the overall acceptance of the developed computational tool in enhancing teaching-learning experience in pipe flows. While analysing the user inputs, the entries on a numeric scale of one to five has been interpreted as 'Don't like', 'Somewhat like', 'Okay', 'Good work' and 'Appreciate greatly', respectively. As per this adaptation, the figure shows that about 50% of the users provide a greatly positive endorsement for this tool, while another 35% of the population applaud this work. The rest 15% of the population affirm the new computational tool to be 'okay' in its usefulness and none of the users provided a lesser rating for the developed innovative tool,

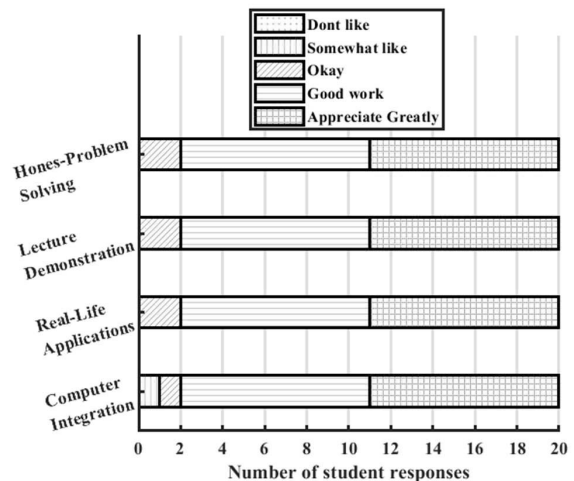


**Fig. 12 : Students' perceptions regarding the role of pipe flows computational tools in promoting instructional aspects of the course.**

which validates our claim regarding the overall usefulness of the tool.

#### B. User perceptions on aiding Self-learning

Figure 11 displays a bar plot of the students' perceptions regarding the role of computational tool in aiding self-learning of the concepts related to hydraulic losses and engineering design of pipe systems for fluid flow application. As the figure shows, under all the different segments such as the role of the tool in reducing the difficulty of the pipe flow concepts, promotion of cooperative learning, its usefulness in sustaining the interest of the students in the learning of fluid mechanics and pipe flows, as well as facilitating quality improvement of the course delivery, about 12 users have greatly appreciated this initiative, while another 6 users have applauded the initiative as a 'commendable work'. There was no user who opted for the 'Don't like' option under any of the divisions under this group. This makes the cardinal role of these computational tools in assisting self-learning of students, amply clear.

#### C. User perceptions on Instructional aspects

The response of the users from another standpoint of improvement in the instructional aspects of the course delivery has then been examined. Figure 12 again shows that an enormous majority (nine users under each) of the user population has commended the usage of the developed computational tools on friction factor and hydraulic losses in pipe flows by providing the highest and the next highest rating, respectively.

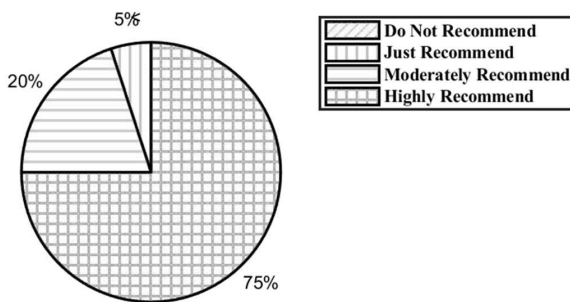


**Fig.13: User responses regarding their recommendation of introduction of such tools in other engineering courses.**

There was hardly one user who ‘somewhat liked’ the usage of computational tools as far as the integration of computers in engineering professions is concerned. This is not surprising since the adoption of a completely novel pedagogy to engineering problem-solving through sophisticated tools may put some in a state of discomfiture, particularly if they are not comfortable with computers. This is expected since some students show a marked preference to ‘pen-and-paper’ and ‘pattern-recognition’ approach to problem solving. However, even this student seem to have appreciated the role of the proposed innovation in imparting real-life engineering skills, its importance in honing problem-solving skills during tutorial sessions and that it can be befittingly used as an excellent lecture demonstration to aid student learning. Overall, the data testifies to the effectiveness of the developed tools in enhancing instructional aspects of the course delivery.

#### D. Recommendation for Other Courses

Finally, it would be worth knowing the opinions of the users regarding the recommendation of such a

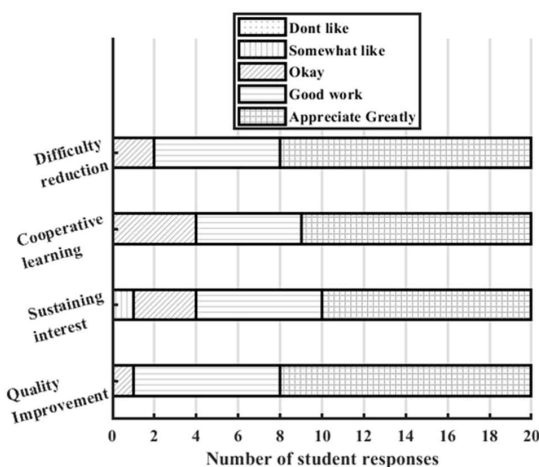


**Fig. 11 : Students' perceptions regarding the role of pipe flows computational tools aiding self-learning.**

pedagogy to other engineering domains. This may be important to know before we can generalize the observations procured from a single Fluid mechanics course, and may extrapolate it to the other courses in Mechanical engineering such as Strength of Materials or Manufacturing technology. However, unlike other questions, while answering this question, the users were provided with only four options: ‘Don’t recommend’, ‘Just recommend’, ‘Moderately recommend’ and ‘Highly recommend’. Figure 13 evinces the quantitative evidence of the user responses. As it shows, the user responses lie within the top three affirmative categories only, with 75%, 20% and 5% responses, respectively. This clearly explicates the notion of the engineering users that such a pedagogy must be introduced in other engineering courses as well.

#### E. Analysis of the Hypothesis testing results

Hypothesis testing is a way to find out whether a hypothesis in respect to a population can be considered acceptable. A hypothesis is basically a presumption about something. The actual test begins by considering two hypotheses: the null hypothesis ( $H_0$ ) and the alternative hypothesis ( $H_a$ ). The alternative hypothesis is a claim about the population that is contradictory to  $H_0$  and what is naturally concluded upon rejection of  $H_0$ . Since the null and alternative hypotheses are contradictory, one must examine evidence to decide if there exists enough evidence to reject the null hypothesis or not. The evidence is in the form of sample data. After it has been determined which hypothesis the sample supports, two possible decisions could be made: “reject  $H_0$ ” if the sample information favours the alternative hypothesis or “decline to reject  $H_0$ ” if the sample information is insufficient to reject the null hypothesis. For instance, the first hypothesis (of the ten hypotheses presented in this manuscript) as presented in Table 1 can be written technically as follows:

$H_0$ : The developed computational tool does not considerably improve the overall teaching-learning experience of pipe flows.

$H_a$ : The developed computational tool considerably improves the overall teaching-learning experience of pipe flows.

On the basis of population and type of data, there are many tests that can be used for hypothesis testing.

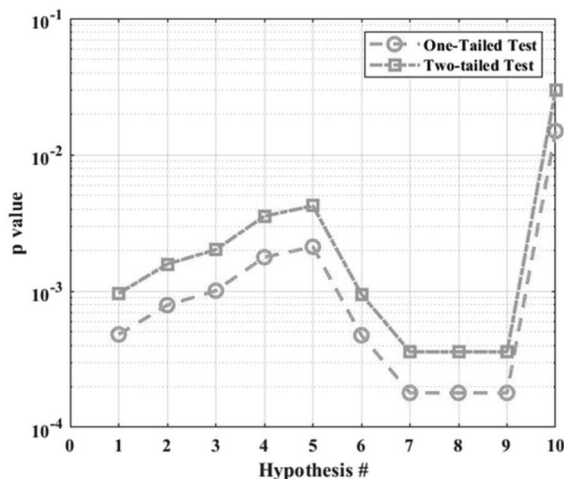


**Fig. 14 : p values for all hypotheses presented in Table 1, using 'One-Tailed t-test' and 'Two-tailed t-test'.**

Out of all these several tests, the “t-test” is considered most suitable for the present population, and thus we have conducted both ‘One-Tailed test’ and ‘Two-tailed t-test’ to calculate the p value, which in statistics is the probability of obtaining results at least as extreme as the observed results of a hypothesis test, assuming null hypothesis to be correct. Thus, a smaller p value ( $< 0.05$ ) implies that the alternate hypothesis is correct. The “t-test” feature is in-built in Excel under the Data analysis tool pack section in which variable range can be selected and it gives the output of mean, number of observations, variance and p value for ‘One-tailed t-test’ and ‘Two-tailed t-test’.

Figure 14 presents the p values for all the hypotheses presented in Table 1. As the figure shows, there is a slight variation between the p values of different hypotheses, but the trends of variation of One-Tailed test and Two-tailed test remain the same. Further, the upper bound of these p-values are 0.002 and 0.0044, and since p value is lesser than 0.05 for all the hypotheses, these represent statistically significant test result, i.e. the null hypothesis is false and must be rejected for all the statements presented in Table 1. Thus, the results of hypothesis testing clearly and definitely substantiates the usage of these computational tools in the fluids education in particular, and to some extent, engineering education in general. It is expected that the development of such computational tools may open a new foray into which concerted development of engineering pedagogy could take place, and which has a potential of transforming both engineering education in terms of delivery and self-learning.

## 6. Conclusion

The approach developed in this paper for solving four types of pipe flow problems provides a reliable, efficient means of explicitly determining a variety of design parameters for pipe flow problems. Manual solutions to these types of problems requires time and is a difficult process as it involves iterative calculations. This approach also provides an efficient technique to enhance real-time modelling, which requires the reliable, fast calculation of many of the parameters discussed in this paper. The paper demonstrates the use of spreadsheets as an educational tool in the area of analysis of hydraulic losses in pipes. In addition to helping the student understand the concepts of analysis and design, it clarifies the concepts behind solving the set of governing equations. Certain features like Goal-seek method inherent to spreadsheets were used to perform the iterative calculations needed for the friction factor and the ‘macros’ feature of MS-Excel was used to automate the solution. Spreadsheets are invaluable for the instructor also since it helps him design better assignments and test problems. Other platforms were also available for designing of computational tool, but MS Excel provides the maximum ease in designing such tools and is more student-friendly due to its inherent simplicity. User surveys were also conducted to find out whether this design helps students and instructors in effective ways. Detailed reviews were taken from the users on eight different aspects and the user responses were found overwhelmingly positive on all the fronts – both from the viewpoints of improvement in instructional aspects of the course as well as its effectiveness in aiding self-learning for students. Using the data gathered from the users, a hypothesis testing was done to validate the ten hypothesis statements, and a p value lower than 0.05 for all the hypotheses allows us to conclude that the proposed computational tools are found to be extremely effective both for teaching and learning purposes. In addition, the users strongly recommend such interventions in other engineering courses. To sum it up, the current manuscript does not only report the design of relevant computational tools for the teaching and learning of pipe flows in the undergraduate fluid mechanics curriculum, but also presents the detailed methodology that can provide enough cues to one who wishes to design such computational tools. The developed computational tool has been provided on a self-created open-source website ([drkarnteaching.com/](http://drkarnteaching.com/)) freely to be used by the students and engineering instructors alike.

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# Emerging Trends and Knowledge Domain in Vocational Education : A Global Perspective

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**Abstract :** In the recent past, the Vocational Education (VE) has been an emerging concern/area of higher education in India as well as in other nations. Global research has shown that publications in VE are also a key concern and one of the emerging areas of higher education. The purpose of the research study is to evaluate the global research trends in VE based on the bibliometric data collected on 10th February 2021 from the Scopus database from the publication year 1948 to 2021 for 73 years. The findings of the study reveal that 4003 scientific/research articles were extracted related to VE, in which the United Kingdom topped with 1140 publications. Among the most productive (a greater number of articles published) institutions, Universiti Tun Hussein Onn Malaysia was found to be the topper with 168 publications. The Journal of Vocation Education and Training was the top journal that contributed the largest publication with 786 articles.

**Keywords :** Vocational Education, Higher Education,

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Bibliometrics, Scopus Database, Educational Research, Scientific Production.

## 1. Introduction

The 21st century has witnessed a rise in the field of VE in a global education scenario. VE research is currently a well-established international topic of educational research (Rauner & Maclean, 2008). With varied histories, self-concepts, aims, curriculum, institutions, and practices, VE is often highly regional and nationally focused (Gessler et al., 2021). VE is an integral part of skill development. VE yields higher returns than the same from general education (Agrawal & Agrawal, 2017). Learning in VE (VE) requires strategies that match characteristics, appropriate targets, clear goals, measurable competencies, and indicators. (Nurtanto et al., 2020).

The emergence of research in VE and the trend of researching VE have increased over a while. The country's contribution to the concerned research field is accountable in the publication world. Countries show an extensive difference in their stress on VE (Rodgers & Boyer, 1993). This study aims at evaluating the research trend in VE essentially at the global level as the research is the second dimension of higher education, it is also important to analyse the existing research field of VE in terms of its Productive authors, leading countries, top sources, author collaboration, country collaboration, etc.

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## 2. Rationale Of The Study

There had been no research information about global research trends in VE, and so far, no research has examined at the bibliometric factors in this domain. As a result, this study is an attempt to understand the research trends and knowledge domain in the field of Vocational Education. There is a demand in order to conduct and analyse the global research trends in VE based on bibliographic variables which can bridge the gaps between VE and research in the global scenario. This research paper, comprehends the major emerging research trends and knowledge domain and delivers a global perspective for the present and the future researchers, educators, policymakers and funding agencies in the VE domain.

## 3. Objectives Of The Study

To evaluate the selected bibliometric variables in VE Publications from the Scopus database like the global annual scientific production, the most productive authors, author collaboration, institutions, sources, country collaboration, and creating a word cloud for the authors' keywords, all keyword collaborative clusters. All the results of the objectives were presented in tables and figures.

## 4. Literature Review

VE and its skill development among youth are important for the global economy. In developing nations, skill development is increasingly seen as a method to break free from the cycle of low education and high unemployment (Jain et al., 2019). Young people's VE can help them overcome the difficulty of finding work (Shepherd, 2019). VE is primarily concerned with 'applied learning,' or the acquisition of information, skills, attitudes, and ethics suited for the workplace to enhance possibilities for productive employment, sustainable livelihoods, personal empowerment, and socioeconomic growth (Sithole, 1998).

The establishment of skills qualification frameworks, such as the National VE Qualifications Framework (NVEQF) recently established in India, is being pursued by all nations in South Asia. VE is becoming a key component of national human resource development strategies in Gulf Cooperation Countries (Mellahi, 2000). In many countries around the world, VE has been the subject of reform

(Chappell, 2003). From the second part of the twentieth century forward, VE became increasingly essential in meeting the needs of mass higher education (Moodie, 2008). Beyond Europe, policymakers in other developed nations ensure that VE and training meet both the demand for a flexible workforce and the need to equip workers with a broad range of skills and knowledge (Balatti & Black, 2011). India's population is growing, resulting in over a million untrained and undereducated people, as well as a talent shortage. They could benefit from VE and training (Keep, 2012). In Europe, VE has resisted standardizing to a greater extent than other disciplines of study. International, comparative VE research has grown in popularity during the last decade (Christian H. Jorgensen, Ole J. Olsen, 2018).

Higher education is more theoretical than VE, which is more practical and has a greater vocational focus. Because of the increasingly global economy and fierce competition, the higher education sector is a key sector, owing to the growing demand for educated workers who are employed internationally (Vrat, 2012). VE is seen as a critical component in enhancing or sustaining the company and national economic competitiveness. VE reduces unemployment by equipping persons with employable skills. It enhances the students to meet their economic demand in the employment market. VE enables the students to find jobs with skill development. There is a strong association between systematic VE and the successful economy of a country (Cantor, 1991). The scarcity of suitable skills is one of the major reasons contributing to the growth in unemployment. This is known as the 'skills-deficit model' of unemployment (Wellington, 1986). Teacher skills in VE are built on a continuous process of growth to perceive those competencies holistically (Ana et al., 2020).

Most emerging countries have high rates of young unemployment. Secondary school vocational skills training has been regarded as one of the primary methods of equipping young people with the essential abilities, with the underlying premise being that a lack of skills is the most significant impediment to employment (Okwuanaso, 1985). A variety of programmes are being implemented around the country to boost the VE and employment possibilities of women and girls (Terms, 1985). The major way of offering more effective VE for both adolescents and adults is competency-based VE (Watson, 1991). As seen by initiatives in India, Sri Lanka, the Philippines,

Zimbabwe, Nigeria, Kenya, and Ghana, VE has continued to be pursued in the many educational reforms tried by emerging nations (Abrokwa, 1995). The use of modern technology in the learning process, particularly in VE, can draw attention and possibly speed up learning (Nurtanto et al., 2020). In cooperation with the Ministers of Education (MHRD) and Labour, the Government of India introduced the VE Scheme in its early five-year development plans (J.P.Gupta, 1996).

Interdisciplinary educational research focuses on VE. Scholars in allied fields are likewise interested in the international collaboration that is linked with VE (Li & Pilz, 2021). VE research is a distinct educational field that is linked to the mouldings of the transition from schooling to employment. The emergence and origins of didactic techniques and conceptions of vocational teaching and learning, as well as their research context (Zhao, Zhiquan, 2014). Scientometrics has grown in popularity as both a subject of study and a set of methodologies (Sooryamoorthy, 2020).

The productivity of scientific products is evaluated quantitatively using bibliometric approaches (Dervis, 2019). The frequency with which two previous texts are mentioned by a subsequent text is known as co-citation (Liu & Hu, 2021). When two articles are referenced in the same third article, this is known as co-citation. Co-citation is therefore the antithesis of bibliographic coupling. The citations made by the later or more recently published publications are crucial to this study. Knowledge Mapping is a method of combining knowledge from research and publication in any domain/subject (Thamizhiniyan et al., 2020). Undertaking study in any topic fundamentally requires a researcher to grasp the past, comprehend the present, and forecast the future. Studying the emerging trends and knowledge domain in a subject essentially needs bibliometric techniques.

## 5. Methodology

During February 2021, the screening approach reviewed all references related to “Vocational Education” in the specified search field ‘Title-Abstract-Keyword’ of Scopus database, and 4003 scientific publications contributions were retrieved. As a result, the findings cover a period of 73 years, spanning 1948 to 2021. The data analysis focused on 42 journals that already published articles related to VE as the central subject and include the keywords

Education (al), Vocation (al), or Learning as one of the words in the title of the journal.

### A. Analysis Of Data

Retrieved data were analysed by using three various Bibliometric Analysis and Visualization Tools:

- 1) Bibliometrix- An R Statistical tool used to analyse and establish Global Annual Scientific Production, Top Authors Production over the time, Most Productive Institutions/Affiliations and Sources/Journals, Word Cloud for the Authors Top Keywords, Three Plot Association, Frequency of Keywords, Country Scientific Production and Country Collaboration Map (Aria & Cuccurullo, 2017).
- 2) ScientoPy- version 2.0.3, is a Python script that used to generate Most Productive Countries(Ruiz-Rosero et al., 2017)
- 3) VOSviewer – a software tool used to construct and visualize the Cluster networks for the association of top Authors, Authors’ Keywords and Countries Collaboration (Eck & Waltman, 2019).

### B. Delimitations Of The Study

The study used the data only from the Scopus database and the data retrieval was done on 10th February 2021. This study focused only on the article published in the English language. The limitation of this study was that it only examined research articles published in journals that published more than 20 articles with VE as a central subject and included any of the words Education/(al) or Vocation/(al), or Learning in the title of the journal. Other types of publication documents, such as conference papers, books, book reviews, and editorials, were excluded from the analysis.

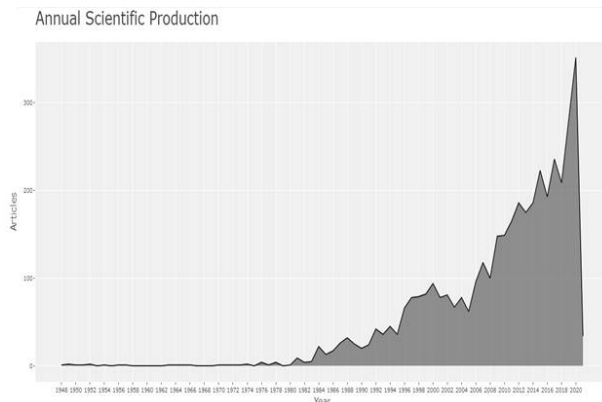
Table 1 depicts the evolution of VE research trends from 1948 to 2021. The number of Journal article papers provided in VE research is 4003. For the whole 73-year period, the compound annual growth rate of AE research production is 5.95 percentage. The VE research works are dispersed over 42 journal sources, including 4726 multi-authored papers and 1136 single-authored documents. The average number of citations per document is 10.78. This table provides a

**Table 1 : Detailed Summary of VE Publications**

| DESCRIPTION                         | RESULT    |
|-------------------------------------|-----------|
| Timespan                            | 1948:2021 |
| Sources (Journals)                  | 42        |
| Documents                           | 4003      |
| Average citations per document      | 10.78     |
| Average citations per year per doc  | 1.015     |
| <b>DOCUMENT TYPES</b>               |           |
| Article                             | 4003      |
| <b>DOCUMENT CONTENTS</b>            |           |
| Keywords Plus (ID)                  | 482       |
| Author's Keywords (DE)              | 6356      |
| <b>AUTHORS</b>                      |           |
| Authors                             | 5862      |
| Author Appearances                  | 8588      |
| Authors of single documents         | 1136      |
| Authors of multi-authored documents | 4726      |
| <b>AUTHORS COLLABORATION</b>        |           |
| Single-authored documents           | 1636      |
| Documents per Author                | 0.683     |
| Authors per Document                | 1.46      |
| Co-Authors per Documents            | 2.15      |

detailed summary of the datasets provided in connection to VE scientific production.

Figure 1 illustrates the number of VE publications over 73 years, commencing in 1948 with one and finishing in 2020 with 282. The number of VE

**Fig. 1: Global Annual Scientific Production in the field of VE**

publications has continuously grown from 1984 to 2020. Furthermore, there was a significant increase in publications in 2020, with 282 being the most. The current year has 34 publications as of 10th February 2021.

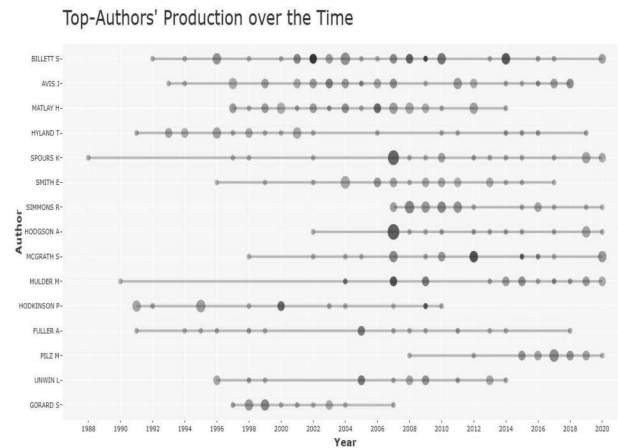
**Fig. 2: Top Authors' Production over the years**

Figure 2 illustrates the top author's performance over 32 years. Among the top 20 authors in the field of AE publishing, Billett S placed first with 35 publications, followed by Avis J with 33 publications and Matlay H with 30 publications. The five authors that generated 20 to 24 publications are Hyland T and Spours K-24, Smith E-23, Simmons R-22, and Hodgson A-20. The other twelve authors have 12 to 14 publications. Spours K used to publish from 1988 until 2020. Figure 2 shows that the year 2007 was the most prolific, with the most publications.

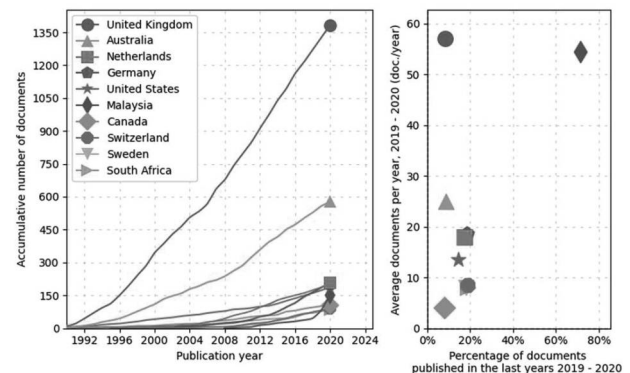
**Fig. 3: Most Productive Countries in VE Publication**

Figure 3 represents the most productive nations up to 2020. The United Kingdom led the publication list with (1348), followed by Australia (577), the Netherlands (209) Germany (200), the United States (187), Malaysia (153), Canada (103), Switzerland (91), Sweden (88) and South Africa (85). Between the

years 2020 and 2021, there was a rise in nation publishing, particularly in Malaysia, which was followed by the United Kingdom.

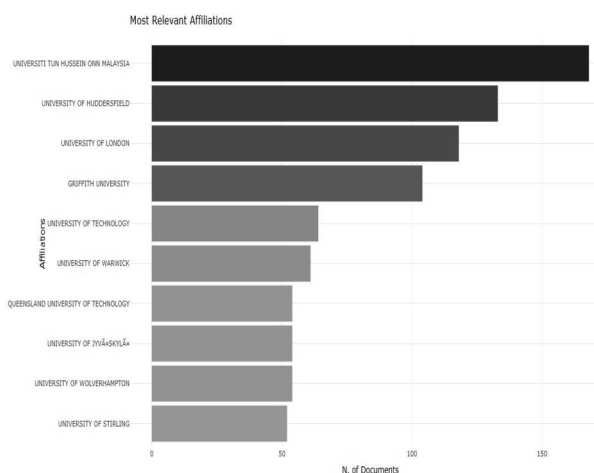


**Fig. 4: Most Productive Institutions in VE Publication**

Figure 4 depicts the top prolific institutions in VE Publication. The top institutions with more than 100 publications were represented by the dark blue colour. Among the top ten institutions, Universiti Tun Hussein Onn Malaysia was found to have the most publications (168), followed by the University of Huddersfield with 133, the University of London with 118, Griffith University with 104, the University of Technology with 64, the University of Warwick with 61, the University of Wolverhampton, University of Jyväskylä, and Queensland University of Technology each had 54 publications, while the University of Stirling had 52.

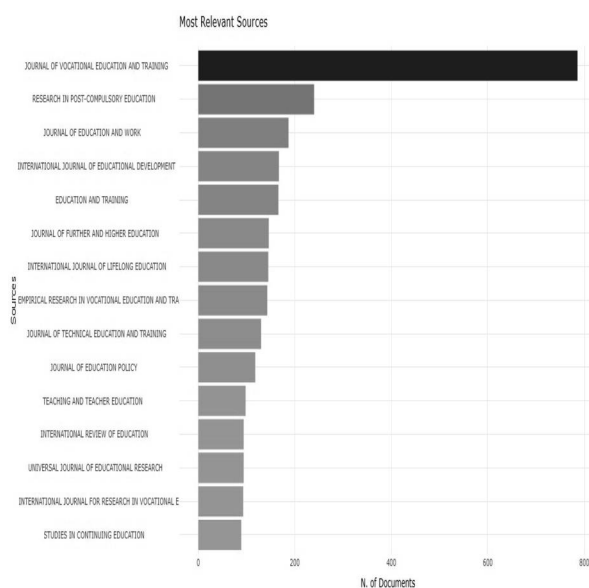


**Fig. 5: Most Productive Sources in VE Publication**

Figure 5 describes the data about the most productive sources of VE publishing. The graph indicated the top twenty journal sources that were significant in VE articles. The results revealed that the topmost journal, Journal of Vocation Education and Training, contributed the most publications with 786 articles, followed by 240 articles in Research in Post Compulsory Education, 187 articles in Journal of Education and Work, 167 articles in International Journal of Educational Development, and 166 articles in Education and Training, followed by other listed journals (Secinaro et al., 2020).



**Fig. 6: Word Cloud of Authors  
Keywords in VE publication**

Figure 6 depicts the construction of a word cloud for the keywords used by the authors in their publications. The word cloud was created with the help of Bibliometrics. The authors' major keyword was VE, which was followed by comparable phrases that were closely linked with VE, such as Higher Education, Further Education, Workplace Learning, Vocational Training, Employability, Lifelong Learning, Professional Development, and so on. This figure highlighted the primary regions of having linked keywords of VE.

The frequency of keyword appearance (all Keywords) in VE research publications was shown to be related to the frequency of bibliometric data analysis. The term VE and Training was used as a keyword 226 times, accounting for 12% of the total publishing situation. Other closely related key terms to VE identified were VE 199 times with 10%, Higher Education 189 times with around 10%, Further Education 122 times with 6%, Workplace Learning 95 times with 5%, VET 94 times with 5%, Employability 74 times with 4%, and Vocational Training 72 times with 4%.

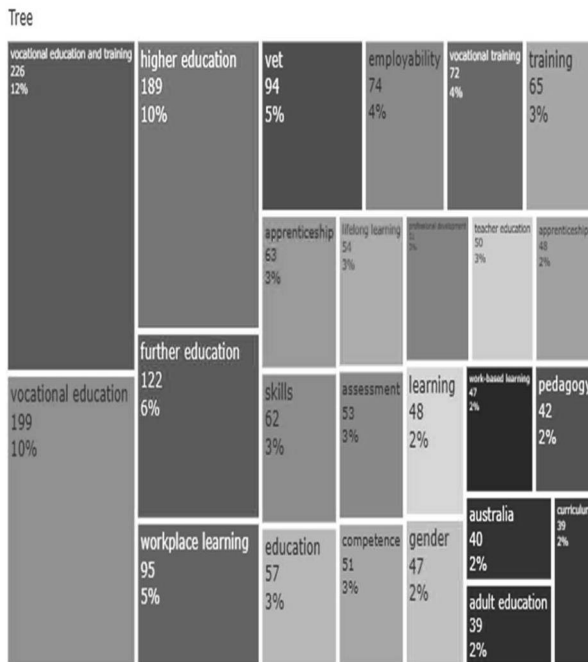


**Fig. 7: Frequency of Keyword Occurrence in VE Research – Keyword Tree of VE**

The important elements in this three-field plot were represented by rectangles in different colours for easy reference. The names of the nations, authors, and sources are represented by the height of the rectangle. The more relationships there were, the higher the rectangle representing the function was.

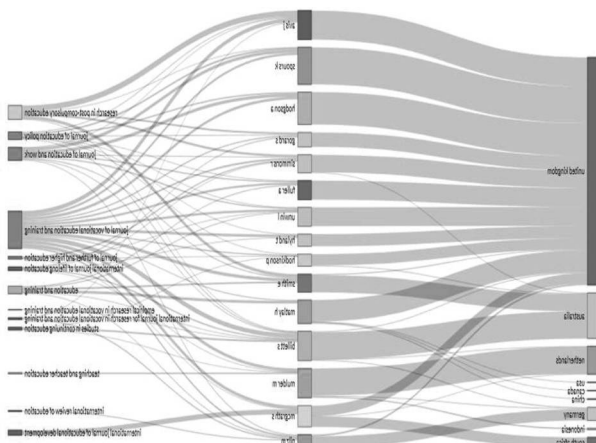


**Fig. 8: Three-Fields Plot Association among top Countries (left), Authors (middle) with Sources (right)**

Figure 8 depicts the connection between the three components. According to the research, the top countries, authors, and sources were (the United Kingdom, Australia, and the Netherlands), and seven authors (Spours K, Hodgson A, Avis J, Mulder M, Billett S, Matlay H, and Mcgrath S) had a strong

association with the three sources; the journal of Education and Work, Research in Post Compulsory Education, and Journal of VE and Training. (Janik and Ryszko, 2020).

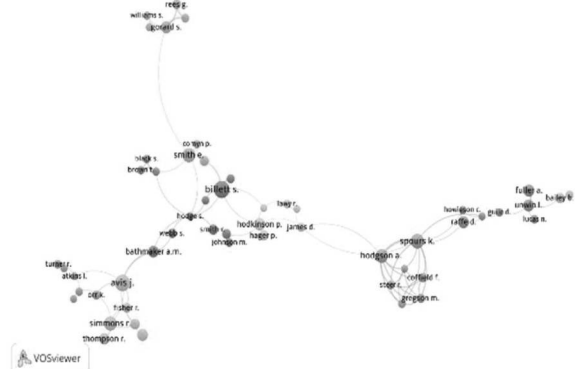


**Fig. 9: Authors Name Collaborative Cluster in VE Research**

The co-authorship analysis cluster of the top fifty-four authors in VE articles is depicted in Figure 9. The network visualisation produced ten total co-authorship clusters, 54 authors with 88 authorship linkages, and 258 total link strengths. The key author collaboration cluster of Billett S, Avis J, and Spours K were the most significant among them.

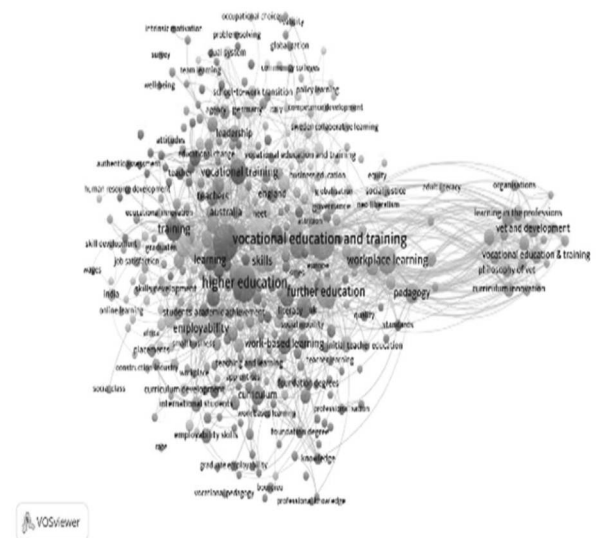


**Fig. 10: All Keywords Collaborative Cluster in VE Research**

The Co-occurrence analysis of all terms from VE articles is shown in Figure 10. The study depicts the collaborative cluster, and the network visualisation output discovered 454 total keys, 11 clusters with 6132 keyword linkages, and 9871 overall link strength. The primary cluster core terms were VE and training, higher education and further education, and so on.

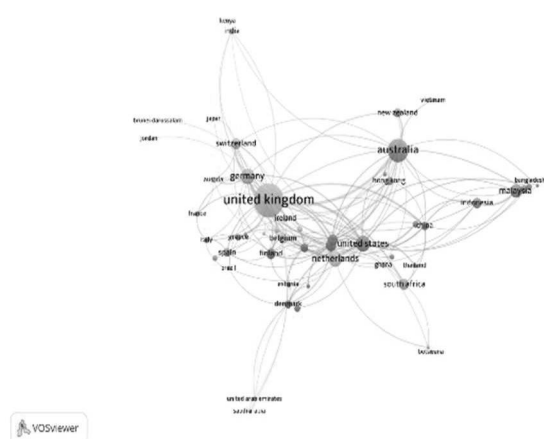


**Fig. 11: Country Collaborative Cluster in VE Research**

Figure 11 depicts a country-by-country examination of all VE articles' co-authorship. The research discovered the collaborative cluster, and the network visualisation output revealed 53 nations forming 11 clusters with 193 collaborative linkages and a total link strength of 486. The United Kingdom, Australia, Malaysia, and the Netherlands have the strongest country collaborative clusters.



**Fig. 12: Country Scientific Collaboration Map in VE Publication**

Figure 12 depicts the results of a social structure study performed for the creation of a Country Scientific Collaboration Map in the VE publication. According to the map, the United Kingdom, the United States, the Netherlands, Australia, Canada, and Finland had the world's top five collaborative research publication networks, putting them at the forefront of exceptionally rapid development. In the field of VE, the collaboration between the United Kingdom and Australia produced 28 publications, followed by a collaboration between the Netherlands and Belgium

with 23 publications, Indonesia and Malaysia with 15 publications, Switzerland and Germany with 13 publications, and collaboration between the United Kingdom and China with 10 publications (Biancone et al., 2020).

## 6. Major Findings

The goal of this paper is to conduct a quantitative, and systematic overview of VE research with bibliometric analysis of all VE-related articles from the Scopus database. The authors of this bibliometric analysis revealed the overall VE research as viewed through the lenses of the top 42 journals listed in Scopus, during the last seven decades.

The result reports a 5.95 percentage compound annual growth rate for AE research output, with an average citation per document of 10.78. The findings indicated that multi-authored documents had a three-fold advantage over single-authored papers. The findings also indicated that in terms of publications, 2007 was the most productive year.

Between 1948 and 2020, the number of VE articles publications has risen 282-fold. It shows that there is an increasing trend in VE research and publication. Between January 1st and February 10th, 2021, the authors deducted a significant rise in the number of publications in a month, with 34. It also demonstrates how fast VE research advances in publication.

The results reveal that 20 authors consistently performed well throughout 32 years in terms of author output. Billett S was ranked top (35), followed by Avis J (33) and Matlay H (30) as the most productive three authors with more than 30 articles. Spours K was one of the top twenty prolific authors in the world who continuously published articles from 1988 to 2020. The article titled "Toward a Workplace Pedagogy: Guidance, Participation, and Engagement" (2002), authored by Billett S, an Australian educational researcher and Professor of Adult Vocational Education in the School of Education and Professional Studies at Griffith University, and published in the Journal Adult Education Quarterly (SAGE Publications), received the most citations (201 total).

Globally 91 countries contributed to VE publications. European countries domination found more in productivity. The United Kingdom was found as the most prolific country in VE research, with an h-

index of 56, followed by Australia with an h-index of 38, the Netherlands with an h-index of 32, Germany with an h-index of 20, and the United States with an h-index of 22. Citation analysis findings found the nations with the highest number of citations. The United Kingdom, like the most productive country, led in overall citations with 14490, followed by Australia (5818), the Netherlands (2814), the United States (1743), Germany (1452), and Finland (942).

The findings revealed that the first five journals in the top ten productive sources (journals), namely *Journal of Vocational Education and Training*, *Research in Post-Compulsory Education*, *Journal of Education and Work*, *International Journal of Educational Development*, *Education and Training*, were all published in the United Kingdom, with Taylor & Francis being the leading publisher among the publishers.

Worldwide, 1864 institutions contributed to VE publications. Four of the top institutions were from the United Kingdom and four were from Australia. Finland and Scotland both had each institution. The cluster and link among the authors in a given subject may be identified using co-author analysis. The findings revealed a total of 88 authorship relationships with ten co-author clusters in this study.

Finding country-by-country Co-authorship revealed that 53 nations were grouped into 11 clusters, each with 193 collaborative linkages. It demonstrates the importance of country collaboration in attaining Multi-Country Publication (MCP). The results also revealed that the United Kingdom, Australia, Malaysia, and the Netherlands have significant country collaborative clusters. Social Structure analysis revealed the scientific collaboration among countries and found that The United Kingdom, the USA, the Netherlands, Australia, Canada, and Finland were the top five collaborative country's scientific publication networks in the world.

India was rated 25th out of 91 nations, with 37 publications. There were 25 single-country articles and 12 multi-country publications among the findings. With an h-index of 8, India earned 141 total citations and 11.7 average article citations. Collaboration between countries identifies India has 12 articles with six-nation collaborations: Germany (four), the United Kingdom (three), Australia (two), Kenya (one), Switzerland (one), and the United States

of America (one). The period between 1984 and 2020 exhibited considerable development in the publishing, it is considered that VE has been a rising issue in the world of literature. Furthermore, in 2020, there was a significant increase in publications, with 282 publications being the most.

## 7. Recommendation And Conclusion

In any country's higher education system, research is the lifeblood of advancement. In India, research is regarded as the second most important aspect of higher education after teaching. VE encompasses Formal, Non-formal, and Informal education and is one of the most multidisciplinary and continually potential areas. Since the research literature in this area of VE is exploding, funding agencies and academic institutions should take necessary measures to trigger scholars' interest in VE research. In terms of publication production growth, author share, institutional, international collaboration, and citation quality in VE research, India lags considerably behind other nations. Developed nations are the leading producers of scholarly papers in VE, and India has to catch up through collaborating with leading authors and countries. Financing is a crucial component in every institution's research growth, and Indian institutions and scholars require adequate funding from national and international agencies to publish a large number of research papers in journals that are listed in international databases like Scopus. To boost production and improve research quality, there should be a significant rise in international collaboration through universities and institutions of National importance by means of Memorandum of Understanding (MoU). In recent past research publications related to VE, international journals are the most productive sources of publications, however, India needs to address this research deficit significantly realising the research facilities.

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# Identification of Effective Scaffolding to Novices Using CBLE

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**Abstract:** The aim of this study is to discover which kind of scaffolding can effectively promote learning. The past studies have shown mixed results in this regard. The process in which a domain expert gives and withdraws support in order to make a novice learner complete the task is known as scaffolding. A total of four distinct scaffold combinations and four groups were made. This experimental study was repeated twice to cross verify the outcomes using computer based learning environment (CBLE). The CBLE was designed with intelligent web program in PHP and jQuery to evaluate the solutions submitted by the learners instantly. The CBLE acted as an intelligent feedback system. In the first study, it was found that there was a significant effect of different scaffolding treatments on the learning outcomes,  $F(3,76) = 5.762, p=.001$ . The result analysis involves multiple comparisons based on Tukey HSD test and indicated that the mean score for the indirect support and adaptive fading ( $M=4.45, SD=1.191$ ) was considerably different than the others. Likewise, second study also found that there was a significant effect of different scaffold treatments on the learning

outcome,  $F(3,76) = 4.258, p=.008$ . The Tukey HSD test applied during the second study indicated that the mean score for the indirect support and adaptive fading ( $M=4.55, SD=1.19$ ) was again significantly different than the others. The present study additionally measured the flow state of all the four groups using Kruskal-Wallis H test and found that indirect support and adaptive fading group was significantly different than direct support and adapting fading group as well as direct support and gradual fading group in both the studies.

**Keywords:** Computer Based Learning Environment (CBLE), Effective Scaffolding, Intelligent feedback system

## 1. Introduction

For a long time, it has been a matter of debate that which type of instructional support is effective to enhance the learning outcome. The withdrawal of support is also necessary in this regard for the independent functioning. The process in which a domain expert teacher gives and withdraws support in order to make the novice learners complete the task is known as scaffolding (Anwar, Irawan, & As'ari, 2017; de Pol et al., 2010; van de Pol, Mercer, & Volman, 2019). The scaffolding can be face to face between students and a teacher or it can be a computer based scaffolding. In computer based scaffolding, a specialized software is designed which regularly

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direct and monitor students and prevent them from engaging in superfluous, misleading and unproductive tactics (Azevedo et al., 2010; Hannafin et al., 1999; Saye & Brush, 2002). This specialized software can be a desktop application or web based application (R. Kaushal, Panda, & Kumar, 2020).

The past studies emphasized primarily on two main characteristics of scaffolding namely “Support or Contingency” and “Fading Support or Withdrawing Support”. This study extended this work by further classifying these two key characteristics and designed an experimental study to find the best combination of scaffolding. In addition, this study also disclosed that which of scaffolding combinations engaged the participants more.

## 2. Related Work

Scaffolding refers to dynamic expert advice to novices in order to complete the task and enhance learning (Collins et al., 1989; de Pol et al., 2010; van de Pol, Mercer, & Volman, 2019; Wood et al., 1976). In scaffolding, expert instructor design tasks and plan strategies which learner can pursue to enhance learning. It is also known as soft scaffolding (Saye & Brush, 2002; Sharma & Hannafin, 2007). Scaffolding cannot function independently rather it is utilized with existing instructional approaches like PBL (Problem Based Learning) (Saye & Brush, 2002), learning by design (Puntambekar & Kolodner, 2005) or CBL (Case-Based Learning (Lajoie et al., 2001).

It is recommended that once learner achieves certain competence level, scaffolding should be withdrawn by the expert to encourage independent functioning (van de Pol & Elbers, 2013). It is necessary to transfer the responsibility back to learners (Pea, 2004; Puntambekar & Hubscher, 2005). The expert can decide when to withdraw scaffolding by observing each student’s performance. The studies in this area agree that there are two essential characteristics of scaffolding, giving support and withdrawing the support, also known as contingency and fading (de Pol et al., 2010; Smit et al., 2017).

In the recent years, computer-based scaffold (CBS) is being utilized to improve learning by supplementing expert instructor scaffolding (Azevedo et al., 2010; Hannafin et al., 1999; Saye & Brush, 2002). In this environment, a software is designed which continuously direct and monitor students and prevent them from involving in

superfluous, misleading and unproductive tactics (Pea, 2004). CBS emerges due to advancement in technology (Devolder et al., 2012). Most computer-based scaffolding systems are static as tasks and strategies are fixed and cannot be changed at runtime. CBS is also known as fixed and hard scaffold (Saye & Brush, 2002; Sharma & Hannafin, 2007).

Moreover, the tasks designed in computer-based scaffold should neither be too easy nor too difficult (Applebee & Langer, 1983; Bliss et al., 1996; Gaffney & Anderson, 1991). One biggest challenge with computer-based scaffold is to decide when to withdraw scaffolding. Generally, it is withdrawn at some fixed point (Li & Lim, 2008) or when learners himself do not need it (Metcalf, 1999). Building an intelligent computer based scaffold that can judge and fade support automatically is difficult (Puntambekar & Hubscher, 2005).

Most of the studies in this area did not consider learner characteristics. In fact, learner characteristics should also be considered in computer-based scaffolding (Hannafin et al., 1999). The learner characteristic like prior knowledge can influence the learning outcome in a scaffold environment (Devolder et al., 2012). Majority of the studies in this area are observational (Cazden, 1979; Englert, 1992; Langer & Applebee, 1986) and very few studies are experimental based (Palincsar, 1986, 1991; Palinscar & Brown, 1984) and has proved the effectiveness of scaffolding.

The related literature primarily highlights on two essential characteristics of scaffolding, giving support and withdrawal of support. But, a research is still required to find which combination of scaffolding can effectively promote learning as support and withdrawal can further be categorized. The “support characteristic” can be classified as direct and indirect support. The “withdrawal of support or fading characteristic” can be classified as adaptive fading and gradual fading. The present study examines the most effective way of scaffolding by making all possible combinations of scaffolding characteristics by keeping the fact in mind that each combination must have one element of support and one element of fading. The CBLE helped the domain expert in this context.

## 3.Objective

The aim of this study is to find which combination

of scaffold characteristics can effectively promote learning. A total of four distinct scaffolding combinations and four groups were made. The learning outcomes of all the groups were compared to find the effective combination. The null and alternate hypotheses are stated below.

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$$

H1: Mean of two or more groups would be different

The null hypothesis states that all combinations of scaffold characteristics would be equally effective. Another objective was to investigate which combination of scaffold characteristics would highly maintain the flow level. The null and alternate hypothesis of the second objective is stated below.

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$$

H1: Mean of two or more groups would be different

#### 4. Methodology

This study investigated the most effective combination of scaffold characteristics by making all possible combinations of scaffold characteristics by keeping the fact in mind that each combination must have one element of support and one element of fading. All possible scaffolding combinations and associated groups are stated below.

1. Direct Support & Adaptive Fading (Group 1)
2. Indirect Support & Gradual Fading (Group 2)
3. Direct Support & Gradual Fading (Group 3)
4. Indirect Support & Adaptive Fading (Group 4)

Thereafter, an experimental study was designed and the participants were randomly allocated to one of the four groups where each group faced a unique combination of scaffold characteristics.

##### A. Participants

The study was conducted twice, firstly at Chitkara University, Punjab state and then at Chitkara University, Himachal state. Total 93 students of BCA (Bachelor of Computer Applications) first year willingly participated in the first study. In the second study, 101 students of CSE (Computer Science

Engineering) second year have participated. The study was conducted twice to cross-verify the outcomes. All participants were of age group between 19-20 years.

##### B. Material

A CBLE was developed to conduct the study. The CBLE acted as a resource platform and was designed in WORDPRESS, PHP and JQuery. It consists of animated tutorials on the topic used in the study. The idea was to teach the concept of “infix to postfix conversion using stack” using CBLE. The students were directed to use headphones/earphones during the study. The students were also educated to move to “Take the Challenge Section” of CBLE once they felt confident in solving the tasks.

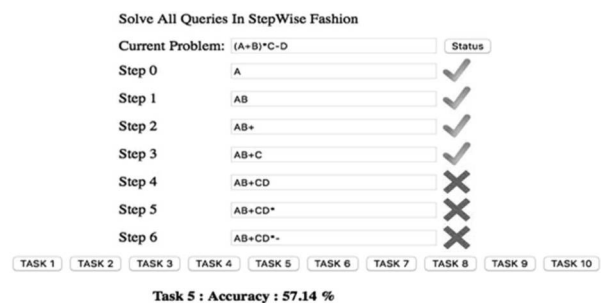


Fig. 1: CBLE immediate feedback environment

The CBLE was designed with 10 challenges/tasks. The domain expert teachers were instructed to support the students in solving the tasks during task solving phase. The support and withdrawal of support by the domain expert were distinct in each group.

The CBLE was designed to automatically evaluate the solutions submitted by the participants. The CBLE web platform was smart enough to track which student belongs to which group due to the mandatory registration process required before the start of the study. This automatic evaluation was performed through the jQuery and PHP code at the backend. The backend logic was using data structures algorithm to track the accuracy of the learner's solution. As a result, participants could get instant feedback in terms of accuracy level in percentage. This feedback helped the domain expert to decide when to withdraw support. The CBLE environment is shown in the Fig. 1. Introducing CBLE into scaffolding has already proved effective in the past. (González-Gómez & Jeong, 2019) also used such learning platform while scaffolding and named it as computer based blended scaffolding. (Denny et al., 2019) also supported the

use of software tools during the metacognitive scaffolding. This learning platform was designed using Adobe Captivate 6 and HTML 5. The poor accuracy level was subject to more support and higher accuracy level was subject to withdrawal of support. All the four groups faced the same challenges.

### C. Procedure

A prior knowledge test was conducted before dividing the subjects into groups. The idea was to include low prior knowledge students in the study. A prior knowledge test comprises of 8 multiple choice questions was conducted.

The study was conducted on the data structures concept of “infix to postfix conversion using stack”. All participants who scored more than 3 marks were excluded from the study as the study only needs low prior knowledge students. As a result, 13 participants were excluded from the first study due to the exclusion criteria. The remaining 80 participants were randomly allotted to one of the four groups (20 students in each group). Similarly, 21 participants were excluded from the second study after prior knowledge test.

Both the studies were restricted to incorporate 80 participants only as the university allotted only four labs of 20 computers each for the study. Thus, first 80 students were included according to the inclusion criteria. Due to this, we had to exclude some students even after they matched the inclusion criteria.

A separate lab was allotted to each group along with a dedicated expert teacher. Four university teachers of computer applications department took part in conducting the study. A CBLE (Computer Based Learning Environment) was also introduced to all the groups which acted as a learning portal and for automatic evaluation of student's performance.

Once the study is completed, a post-test, including 3 infix to postfix problems and 3 multiple choice questions, of 40 minutes was conducted to measure the learning outcomes of each group. The participants were instructed to switch off the computers before appearing for the post-test exam. Additionally, a questionnaire was given to participants of each group to measure the level of flow.

The one-way ANOVA test was applied to post-test data of both the studies to measure the performances.

The Kruskal-Wallis H test was applied on questionnaire data-set to measure which combination of scaffolding maintains a higher level of flow.

The flow theory was initially established by Csikszentmihalyi and it was defined as the state in which a participant feels entirely engaged in the activity and focuses completely on the task at hand (Csikszentmihalyi, 1990). He also proposed flow items to be used in a flow questionnaire. Later on, Jackson and his colleagues worked on the same theory for improvement purposes. They modified some of the original items.

After validity and reliability testing, a short flow state scale and a questionnaire were proposed along with the way of measuring flow score (Jackson et al., 2008; Martin & Jackson, 2008) by Jackson and his colleagues. This study was not aimed at establishing new flow constructs and scales. As a result, it utilized the same well-established constructs and scale to measure the flow scores. A total of 9 questions were asked based on the 9 constructs (See Table 1) to measure the flow state score.

The Likert scale based on five-point were used in the questionnaire, 1 being the lowest (Strongly Disagree) and 5 being the highest (Strongly Agree). Jackson and his colleagues also suggested that flow score of each participant should be measured by calculating the sum of all nine responses and then dividing the total by nine. The similar method was applied in this study.

## 5. Treatment In Various Groups

The four groups were made in the study due to four distinct scaffolding combinations. In each group, there was one element of support and one element of fading. All the groups faced different treatments due to distinct scaffolding combinations during solving the tasks. The CBLE was incorporated with 10 distinct challenges/tasks. The nature of all the scaffold characteristics (direct support, indirect support, adaptive fading, and gradual fading) are discussed below.

The domain experts were instructed to provide and withdraw support during the problem solving phase. The domain expert support was classified as direct and indirect support. The way of direct support was to support students by highlighting their mistakes and

**Table 1 : Flow-State constructs and corresponding statements**

| Construct (Flow)                       | Corresponding Statement                                                                  |
|----------------------------------------|------------------------------------------------------------------------------------------|
| "Balance Between Challenge and Skills" | "I felt I was competent enough to meet the demands of the situation"                     |
| "Merging Actions and Awareness"        | "I did things spontaneously and automatically without having to think"                   |
| "Focus on Clear Goals"                 | "I had a strong sense of what I wanted to do"                                            |
| "Feedback (Unambiguous)"               | "I had a good idea about how well I was doing while I was involved in the task/activity" |
| "Concentration (Task at Hand)"         | "I was completely focused on the task at hand"                                           |
| "Sense Over Control of Actions"        | "I had a feeling of total control over what I was doing"                                 |
| "Loss of Self Consciousness"           | "I was not worried about what others may have been thinking of me"                       |
| "Transformation (Time)"                | "The way time passed seemed to be different from normal"                                 |
| "Experience (Autotelic)"               | "I found the experience extremely rewarding"                                             |

then by giving solution directly through demonstration. The way of indirect support was to support students in completing the task by giving them hints, clues or suggestions. So, in this kind of support domain experts were bound for not giving direct solution through demonstration.

The fading characteristic was classified as adaptive and gradual fading. The adaptive fading indicates that the support needs to be completely withdrawn when the performance is satisfactory and support should be delivered again when the performance degrades. In fact, learners were allowed to call domain expert for help whenever they faced problems in solving a task.

The gradual fading indicates that support needs to be withdrawn gradually in decreasing order. The students were told to solve all 10 tasks during the study on CBLE. In gradual fading, students were allowed to take support for any number of mistakes committed while solving the first task. So, 100% support of domain expert was available. In the second task, they were eligible to take help only if they got a minimum of 20% marks. So, it means they could only get remaining 80% support from the domain expert. In the third task, they were eligible to take help only if they got a minimum of 30% marks. So, it means during the third task they could only get remaining 70% support from the domain expert. In the second last task, the accuracy needed to get support was 90%. So, domain expert could only support for remaining 10% mistakes. The support was fully withdrawn in the last task.

Initially, students were not aware of their groups. Once all the groups settled down in their dedicated labs, the domain expert teacher informed them their group number and the type of treatment. Thereafter,

the participants were instructed to register themselves on CBLE. It was mandatory for the participants to register themselves in their corresponding group on CBLE.

## 6. Results

### A. Study 1 Results

The post-test data of the first study was analysed using IBM SPSS 23. The Shapiro-Wilk normality test was applied on the post-test scores of all the four groups, 20 subjects in each group, and data was found normally distributed with a p value of 0.323 for direct support and adaptive fading group (DSAF), 0.096 for indirect support and gradual fading group (ISGF), 0.075 for direct support and gradual fading group (DSGF) and 0.050 for indirect support and adaptive fading group (ISAF).

The Shapiro-Wilk test assumes normality if  $p \geq .05$ . Thereafter, the present study conducted a Levene test and discovered that the assumption of homogeneity of variance was met,  $p=0.532$ ; therefore, one-way ANOVA was carried out (See Table 2).

The different combinations of scaffolding had positive impact on the learning outcome,  $F(3,76) = 5.762$ ,  $p=.001$ . A Tukey HSD post-hoc comparison test was conducted (See Table 3) to identify which combination of scaffolding outperformed in the study.

The Tukey HSD test showed that the mean score for the ISAF ( $M=4.45$ ,  $SD=1.191$ ) was considerably different than DSAF ( $M=3.15$ ,  $SD=1.53$ ), ISGF ( $M=3.15$ ,  $SD=1.66$ ) and DSGF ( $M=2.60$ ,  $SD=1.42$ ).

**Table 2 : One-way ANOVA test results on post-test scores**

| (I) group | (J) group | Mean Difference (I-J) | Std. Error | Sig.  | 95% Confidence Interval |             |
|-----------|-----------|-----------------------|------------|-------|-------------------------|-------------|
|           |           |                       |            |       | Lower Bound             | Upper Bound |
| DSAF      | ISGF      | .000                  | .463       | 1.000 | -1.22                   | 1.22        |
|           | DSGF      | .550                  | .463       | .636  | -.67                    | 1.77        |
|           | ISAF      | -1.300*               | .463       | .031  | -2.52                   | -.08        |
| ISGF      | DSAF      | .000                  | .463       | 1.000 | -1.22                   | 1.22        |
|           | DSGF      | .550                  | .463       | .636  | -.67                    | 1.77        |
|           | ISAF      | -1.300*               | .463       | .031  | -2.52                   | -.08        |
| DSGF      | DSAF      | -.550                 | .463       | .636  | -1.77                   | .67         |
|           | ISGF      | -.550                 | .463       | .636  | -1.77                   | .67         |
|           | ISAF      | -1.850*               | .463       | .001  | -3.07                   | -.63        |
| ISAF      | DSAF      | 1.300*                | .463       | .031  | .08                     | 2.52        |
|           | ISGF      | 1.300*                | .463       | .031  | .08                     | 2.52        |
|           | DSGF      | 1.850*                | .463       | .001  | .63                     | 3.07        |

\*. Significance at 0.05

The present study also evaluated that which combination of scaffolding maintains higher level of flow. To measure this, Kruskal-Wallis H test was applied on the questionnaire data-set which implied a considerably significant difference in flow state between different scaffolding treatments,  $X^2(3) = 19.774$ ,  $p = .001$ , with a mean rank score of 37.25 for DSAF, 43.05 for ISGF, 24.80 for DSGF and 56.90 for ISAF. Dunn's pairwise tests were then conducted for all pairs of groups. There was a convincing evidence ( $p < 0.001$ , after the Bonferroni correction) of a difference between DSGF and ISAF group. The difference between DSAF and ISAF was also significant ( $p = 0.045$ , after the Bonferroni correction). There was no evidence of a difference between the other groups.

**Table 3 : Tukey Post-Hoc comparison results**

| (I) group | (J) group | Mean Difference (I-J) | Std. Error | Sig.  | 95% Confidence Interval |             |
|-----------|-----------|-----------------------|------------|-------|-------------------------|-------------|
|           |           |                       |            |       | Lower Bound             | Upper Bound |
| DSAF      | ISGF      | .000                  | .463       | 1.000 | -1.22                   | 1.22        |
|           | DSGF      | .550                  | .463       | .636  | -.67                    | 1.77        |
|           | ISAF      | -1.300*               | .463       | .031  | -2.52                   | -.08        |
| ISGF      | DSAF      | .000                  | .463       | 1.000 | -1.22                   | 1.22        |
|           | DSGF      | .550                  | .463       | .636  | -.67                    | 1.77        |
|           | ISAF      | -1.300*               | .463       | .031  | -2.52                   | -.08        |
| DSGF      | DSAF      | -.550                 | .463       | .636  | -1.77                   | .67         |
|           | ISGF      | -.550                 | .463       | .636  | -1.77                   | .67         |
|           | ISAF      | -1.850*               | .463       | .001  | -3.07                   | -.63        |
| ISAF      | DSAF      | 1.300*                | .463       | .031  | .08                     | 2.52        |
|           | ISGF      | 1.300*                | .463       | .031  | .08                     | 2.52        |
|           | DSGF      | 1.850*                | .463       | .001  | .63                     | 3.07        |

\*. Significance at 0.05

## B. Study 2 Results

The post-test data of the second study was also analysed using IBM SPSS 23. The Shapiro-Wilk normality test was applied on the post-test scores of all the four groups, 20 subjects in each group, and data was found normally distributed with a p value of 0.119 for direct support and adaptive fading group (DSAF), 0.093 for indirect support and gradual fading group (ISGF), 0.416 for direct support and gradual fading group (DSGF) and 0.050 for indirect support and adaptive fading group (ISAF). The Shapiro-Wilk test assumes normality if  $p \geq .05$ . Thereafter, the present

**Table 4: One-way ANOVA test results on post-test scores**

|                | Sum of Squares | df | Mean Square | F     | Sig. |
|----------------|----------------|----|-------------|-------|------|
| Between Groups | 31.638         | 3  | 10.546      | 4.258 | .008 |
| Within Groups  | 188.250        | 76 | 2.477       |       |      |
| Total          | 219.888        | 79 |             |       |      |

study conducted a Levene test and discovered that the assumption of homogeneity of variance was met,  $p = 0.98$ ; therefore, one-way ANOVA was carried out (See Table 4).

The different combinations of scaffolding had positive impact on the learning outcome,  $F(3,76) = 4.258$ ,  $p = .008$ . A Tukey HSD post-hoc comparison test was conducted (See Table 5) to identify which combination of scaffolding outperformed in the study.

The Tukey HSD test showed that the mean score for the ISAF ( $M = 4.55$ ,  $SD = 1.19$ ) was convincingly different than DSAF ( $M = 3.1$ ,  $SD = 1.37$ ), ISGF ( $M = 3.05$ ,  $SD = 2.01$ ) and DSGF ( $M = 3.15$ ,  $SD = 1.59$ ). These results matched with the study 1.

The flow state was measured using Kruskal-Wallis H test which indicated that there was a significant difference in flow state between different scaffolding treatments,  $X^2(3) = 11.362$ ,  $p = .010$ , with a mean rank score of 31.73 for DSAF, 40.53 for ISGF, 35.13 for DSGF and 54.63 for ISAF. Dunn's pairwise tests were then conducted for all pairs of groups. There was a considerable evidence ( $p = .011$ , after the Bonferroni correction) of a difference between DSAF and ISAF group. The difference between DSGF and ISAF was also significant ( $p = 0.047$ , after the Bonferroni correction). There was no evidence of a difference between the other groups.

**Table 5 : Tukey Post-Hoc comparison results**

| (I) group | (J) group | Mean Difference (I-J) | Std. Error | Sig.  | 95% Confidence Interval |             |
|-----------|-----------|-----------------------|------------|-------|-------------------------|-------------|
|           |           |                       |            |       | Lower Bound             | Upper Bound |
| DSAF      | ISGF      | .050                  | .498       | 1.000 | -1.26                   | 1.36        |
|           | DSGF      | -.050                 | .498       | 1.000 | -1.36                   | 1.26        |
|           | ISAF      | -1.450*               | .498       | .024  | -2.76                   | -.14        |
| ISGF      | DSAF      | -.050                 | .498       | 1.000 | -1.36                   | 1.26        |
|           | DSGF      | -.100                 | .498       | .997  | -1.41                   | 1.21        |
|           | ISAF      | -1.500*               | .498       | .018  | -2.81                   | -.19        |
| DSGF      | DSAF      | .050                  | .498       | 1.000 | -1.26                   | 1.36        |
|           | ISGF      | .100                  | .498       | .997  | -1.21                   | 1.41        |
|           | ISAF      | -1.400*               | .498       | .031  | -2.71                   | -.09        |
| ISAF      | DSAF      | 1.450*                | .498       | .024  | .14                     | 2.76        |
|           | ISGF      | 1.500*                | .498       | .018  | .19                     | 2.81        |
|           | DSGF      | 1.400*                | .498       | .031  | .09                     | 2.71        |

## 7. Discussion and Conclusion

The results of both the studies suggests that the indirect support and adaptive fading was the most effective scaffold combination to enhance the learning outcome. This group outperformed in both the studies. The indirect support might have encouraged the subjects to shift to deep thinking as they were getting support only in the form of hints,

clues, and suggestions. The element of deep thinking positively reflected in their post-test scores. Moreover, the adaptive fading made their life easier as they could take help anytime and support could be increased and decreased accordingly. The direct support prevents students to shift towards deep thinking.

The indirect support and gradual fading treatment was very close in nature to indirect support and adaptive fading. Both the treatments differ only in the fading mechanism. The difference in fading mechanism also reflected in the post-test scores. The similar effect was observed with direct support and adaptive fading group and direct support and gradual fading group. So, we conclude that apart from the type of support, the type of fading also plays a vital role in the learning outcome.

The study also investigated that which combination of scaffolding maintains a higher level of flow. In both the studies, it was found that the flow state level of indirect support and adaptive fading group was significantly higher than direct support and adaptive fading group and direct support and gradual fading group.

The environment in which participants got indirect support was more challenging which in turn helped in making a more competitive environment. This competitive environment led to a higher level of engagement to solve the tasks in hand and thus reflected in the higher level of flow. Such competitive environment needs regular support to maintain the flow. That is why the flow level of ISAF group was statistically higher than DSAF and DSGF groups as they could ask for help anytime and for any number of mistakes. The adaptive fading (support based on performance) along with indirect support helped the participants in maintaining their flow level.

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# Assessment and Attainment of Course Outcomes and Program Outcomes

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**Abstract:** Outcome Based Education (OBE) is an approach in the field of engineering education, accepted in recent years all over the world. Output in terms of Cumulative Grade Points Average (CGPA), pass percentage, etc. has been the traditional measurement in education whereas outcome focuses on the level of transformation and achievement in the student. Every institution endeavours to fulfil its mission through its programs which constitute courses and learning activities. The program objectives guide to form the program outcomes, which need to align with universally accepted graduate attributes. These are mapped to the course outcomes whose knowledge levels can be guided by Blooms Taxonomy. Achievement of program objectives can be judged only through the attainment of program outcomes which are indicated by the attainment of the outcomes of the courses which constitute the program. Therefore, assessment tools and attainment methods for the course outcomes and program outcomes are required to indicate the level of transformation at each level. This paper presents a methodology to calculate the attainment of course

outcomes and program outcomes and provides the recommended threshold values to identify the extent of desired transformation in a student after a teaching learning process. Awareness and implementation of these assessment methods with systematic review of thresholds and consequent course correction measures can have a profound impact on student success and mission accomplishments of institutions.

**Keywords:** Assessment, Attainment, Course Outcomes, Program Outcomes, Outcome Based Education, Blooms Taxonomy

## 1. Introduction

'Assessment drives learning' is an accepted statement across all the domains. Assessment along with the educational objectives and pedagogy is an essential mantra for learning achievement in any teaching-learning process. With time, the educational philosophies have been changing with new definitions. The new paradigm of Outcome Based Education (OBE) has been evolved in the last few decades and is being accepted all over the world. With the change from the traditional teacher centric environment to the transformation teaching, OBE shifts focus to become a learner centric exercise, where outcome is described by what a student is expected to know and can do at the end of the course or program through transformation in attitude, skills and knowledge. The role of instructor thus becomes a

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facilitator rather than a teacher. While what to learn and how to learn are given by program and course outcomes and teaching methods respectively, how much is learnt is brought out by assessment which provides timely course corrections for the learner and the faculty. This aids in the fulfilment of learning objectives leading to the accomplishment of mission of the institute.

Learning is a lifelong activity, starting with K-12 education which may lead to graduation and beyond. Learner can exit at any stage to follow a career of his choice (Jandhyala N Murthy, 2012). Well-developed critical thinking skills are important for dealing with the multi-dimensional nature of engineering problems which are structured on complex thought processes that require evaluation (Aoife Ahern et al, 2019). But each program has predefined objectives and OBE defines the path to fulfill them.

Success for each student is the only goal and it is measured by the student ability to meet the pre-defined outcomes (William G Spady, 1994). The key components of OBE are Vision, Mission, Program Educational Objectives (PEOs), Graduate Attributes (GAs), Program Outcomes (POs), Course Outcomes (COs), Mapping, Assessment, Attainments.

The vision and mission, identified as the direction, destination and the path for an institution in a long term prospective, are evolved by involving all the stakeholders or constituents like students, alumni, parents, professional bodies, faculty, industry, management, etc. considering the scope for its growth and future societal requirements.

Program educational objectives are defined based on the vision and mission of department and the institute. Mapping must be aligned between mission and the PEOs, similarly, between PEOs, POs, PSOs and COs as shown in Fig. 1.

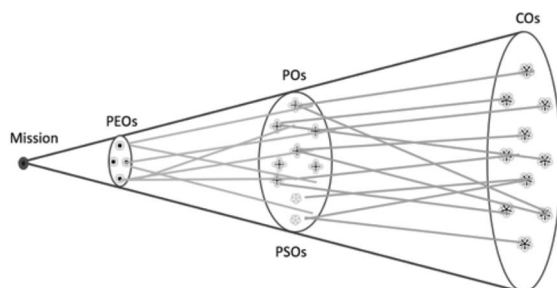


**Fig. 1: Mapping of PEOs, POs, PSOs and COs**

PEOs are the expected achievements of graduated students in their career, during the first few years after graduation. These must be realistic and attainable which address needs of all the stakeholders.

These objectives are deemed to be attained if the student attains or displays desired transformations at the end of the programme. These expected attributes or transformations are known as Program Outcomes (POs). Thus, extent of attainment of PEOs can be gauged through the measurable POs. For universality and standardization, POs are defined based on attributes, which are commonly known as Graduate Attributes (GAs). They are common standard attributes / qualities expected from any graduate from a recognized program from any corner of the world (Washington Accord, 2012). They are as follows.

1. Engineering Knowledge
2. Problem Analysis
3. Design of Solutions
4. Conduct Investigations of Complex Problems
5. Modern Tool Usage
6. Engineer and Society
7. Environment and Sustainability
8. Ethics
9. Individual and Team Work
10. Communication
11. Project Management
12. Life-long Learning

POs are prescribed with the objectives of assurance of quality and relevance to technical education. Generally, a program has 12 POs signifying the 12 GAs. In addition, two to four Program Specific Outcomes (PSOs), may also be needed to signify outcomes which are needed for areas/ domains which are specific or peculiar to a program. PSOs are also evaluated in the same manner as POs. The expected transformations, as signified by the POs and PSOs are delivered through various courses. The number of courses and duration needed

depends on the breadth and depth of the domains needed for the specific programme. Each course shall in turn have 5 to 8 pre-defined Course Outcomes (COs) which describe what students are expected to know and be able to display at the end of the course. These relate to transformations expected in terms of attitude, skills and knowledge that the student acquires as they progress through the course. These must be specific, measurable and student-centred. One of the most important and valuable measurement to identify the outcome level is Blooms Taxonomy.

Course outcomes are articulated as per Revised Blooms Taxonomy from knowledge levels 1 to 6 as shown in Fig. 2. The endeavour is to reach the higher order thinking skills. (Anderson Lorin & Krathwohl David, 2001).

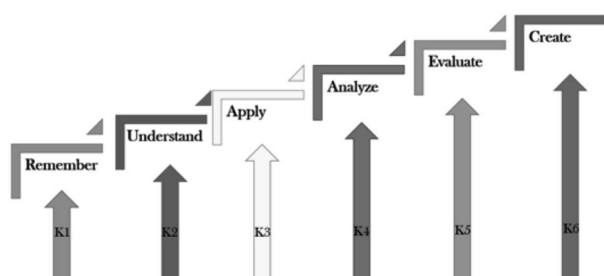


Fig. 2: Revised Blooms Taxonomy

Course outcomes must be written by the course coordinator or module coordinator who is the subject expert and can identify the relevance and importance in terms of knowledge levels by using the appropriate action verbs. Also, they should reflect from both higher order (K4 to K6) and lower order (K1 to K3) as shown in Fig. 3. Five to seven COs can be written for each course. Care should be taken to see that assessment aligns course objectives, by ensuring the knowledge levels being questioned should be of the same level as per the objectives and pedagogical methods.

| CO | Course Outcomes                              | Knowledge Level |
|----|----------------------------------------------|-----------------|
| 1  | Explain basic Engineering properties of .... | K2              |
| 2  | Evaluate various experiments to ....         | K5              |
| 3  | Recognize the shear parameters of ....       | K2              |
| 4  | Analyse the mechanism and ....               | K4              |
| 5  | Distinguish field equipment used in ....     | K4              |
| 6  | Illustrate the importance of ....            | K3              |
| 7  | Assess the mechanism of....                  | K3              |

Fig. 3: Sample Course Outcomes

Examinations play a vital role to assess the extent

of learning by the student and also to classify them as per grades. Examination method and the questions are crucial to highlight the level of learning in a course in particular and hence in a program. Since assessment drives learning, the design of questions needs to cover all levels of learning preferably going beyond simple memory recall. They should also identify suitable PO competencies and performance indicators and test for higher-order abilities and skills. This will help to understand the competencies of students to achieve and forms the basis for the creation of measurable indicators. (Examination Reform Policy, Nov 2018).

Assessment measures effective involvement of the student during learning and also reflects on the effective teaching methodologies. The selection of appropriate assessment method, stage of the course at which the assessment is done and frequency play a key role in the attainment of course outcomes. An assessment can be of two types - formative or summative.

Formative assessment (Assessment for learning) aims to provide feedback and guidance to help students to improve while the course is being carried out on a continuous basis. Whereas Summative Assessment (Assessment of learning) focuses on evaluation of a student's performance, often at the end of a course and provides useful feedback for subsequent assessments (Lorna M. Earl, 2003).

Formative assessment provides insights to both teacher and student on the teaching and learning effectiveness and performance of both. It enables to observe students transformation during the learning process (Huhta Ari, 2010). This helps to measure outcome attainments after each class or session or at any convenient mid-course stage and assists in focussing on knowledge gaps and fine-tuning teaching methodology for maximising teaching-learning effectiveness as the course progresses. Hence, it is also known as continuous assessment.

Summative assessment, as the name suggests, is done after finishing the entire teaching learning process for the whole course assessing the outcome of the completed course. Questions are so designed to cover the essence of the whole course and hence the durations could be longer than the formative assessments. (Lavanya C et al. 2020).

Quantitative measurement of the performance is universally done relying on direct tools like written

tests, quizzes, etc. These direct tools may be inadequate for some academic activities like projects, seminars, presentations, etc, because the number of indicators to judge the level of performance could be varying as per the activity leading to subjectivity. For such cases, a suitable assessment tool is rubric. Rubric tool is ideal to make performance measurements as objective and consistent as possible by defining the criteria (Susan Brookhart, 2013).

## 2. CO-PO Mapping

Program, depending on its duration, may contain one or several courses. Courses are mapped judiciously to ensure progress and to achieve mastery of the learning outcomes given by POs and PSOs. Each course outcome may have varying impact on the program outcome, which is highlighted through CO-PO mapping.

CO-PO mapping is done based on the relevancy or influence of CO on the POs and PSOs. It is represented as high (H) or moderate (M) or low (L) as shown in Fig. 4. This mapping must be done by the subject expert based on the content of the syllabus and its importance as given by knowledge levels, in relation to the program outcomes. Each CO may not

have influence on all the POs, but may have varying relevance on one or more.

During the planning stage, well before the commencement of the course the degree of relevance between CO and PO is rated accordingly. It is customary to give a numerical value of 3, 2 and 1 for high, moderate and low relevancies respectively as shown in Fig. 5. Average can be calculated which suggests the expected value for each PO.

## 3. Attainment of CO

Performance of the student can be reviewed through the attainment process where the student acquires knowledge as they progress through the course. CO attainment is calculated through internal examinations, external or semester end examinations, assignments for both theory and laboratory courses by using direct and indirect methods. Direct methods are used where examinations are conducted and indirect assessment is done through surveys to understand the perception of the stakeholders.

So far overall marks or grades are used to signify the achievement of the student. Higher it is greater is the level of achievement for all the outcomes as a whole. But OBE brings out the importance of GA through POs and COs and allows to review attainment of each outcome through individual questions. Each question is expected to be worded to an appropriate knowledge level thus comprehensively covering all the outcomes of the course.

100% students getting 100% marks is ideal for the achievement. But practically, achieving both is rare though not impossible. So, a pragmatic view is taken through appropriate thresholds. For reasonable achievement for a certain number of students crossing a certain performance is termed as threshold, which if achieved, can periodically be reviewed to raise the level of achievement.

Students are expected to attempt and answer questions and as each question is mapped to one or more COs, students performance is key to extent of attainment of that CO. CO attainment is based on attempt and performance of the students appeared for the examination at a question level. Percentage attempt is the ratio of number of students attempted the question to that of number of students appeared for the examination. If the percentage attempt is less than a threshold value, then attainment is also zero, as less

| Course Code     | Program Outcomes |   |   |   |   |   |   |   |   |   |   |   |
|-----------------|------------------|---|---|---|---|---|---|---|---|---|---|---|
| Course Outcomes | a                | b | c | d | e | f | g | h | i | j | k | l |
| CO1             | H                | M | M |   |   |   |   |   |   | M |   |   |
| CO2             | M                | H |   |   |   |   | M |   |   |   |   | M |
| CO3             | M                | H |   | H |   |   |   |   |   |   |   |   |
| CO4             |                  | H | M |   |   |   | M | L |   |   |   | M |
| CO5             |                  | M | H |   |   |   | M |   |   |   |   | M |
| CO6             | M                |   |   | M |   | M |   | L |   |   | M | H |
| CO7             |                  |   | H | M |   | M | M |   |   | M |   |   |

Fig. 4: CO-PO Mapping

| Course Code     | Program Outcomes |     |     |      |   |   |   |   |   |   |   |      |
|-----------------|------------------|-----|-----|------|---|---|---|---|---|---|---|------|
| Course Outcomes | a                | b   | c   | d    | e | f | g | h | i | j | k | l    |
| CO1             | 3                | 2   | 2   |      |   |   |   |   |   | 2 |   |      |
| CO2             | 2                | 3   |     |      |   |   | 2 |   |   |   |   | 2    |
| CO3             | 2                | 3   |     | 3    |   |   |   |   |   |   |   |      |
| CO4             |                  | 3   | 2   |      |   |   | 2 | 1 |   |   |   | 2    |
| CO5             |                  | 2   | 3   |      |   |   | 2 |   |   |   |   | 2    |
| CO6             | 2                |     |     | 2    |   | 2 |   | 1 |   |   | 2 | 3    |
| CO7             |                  |     | 3   | 2    |   | 2 | 2 |   |   | 2 |   |      |
| PO (Planning)   | 2.25             | 2.6 | 2.5 | 2.33 |   | 2 | 2 | 1 |   | 2 | 2 | 2.25 |

Fig. 5: CO-PO (Planning)

attempt is an indication that the students are not up to that knowledge level. Threshold for attempt percentage can be taken from average attempt percentage for the last three academic years. If it is more than threshold value, then accordingly CO attainment is calculated as per the following procedure.

One reasonable threshold for the level of marks attained is 60% as it signifies first class. Thus, CO attainment is calculated based on the number of students who got more than 60% of marks out of number of students attempted the question. CO attainment percentage is the ratio of number of students who got more than threshold for marks to that of number of students attempted the question. Accordingly, the relevant score for the attainment value is given, taking threshold for number of people attaining as 60%. Therefore, if 60% or more students attain threshold marks then score is 3. If the number of students attaining threshold marks is between 50-59% then the score is 2, if it is between 30-49% the score is 1 and for less than 30%, score is 0. For this example, 30% is taken as the threshold for minimum attempt percentage. Attainment is calculated as per the weightage for formative and summative examination marks which is a direct method.

Also, as part of indirect method, CO attainment is calculated based on the feedback given in the course end survey which is relevant to the course outcomes with the same procedure where total number of students who rate 3 or more on a scale of 1-5, 5 being the high value. Final CO attainment weightage for direct and indirect can be consolidated as below.

$$\text{Final CO} = 90\% \text{ Total CO} + 10\% \text{ Course End survey}$$

This CO attainment procedure as shown in Fig. 6 can be carried for all the courses of the program. Program in its duration may involve curricular activities and beyond also. POs 1 to 5 cover adequately knowledge and skills but POs 6 to 12 indicate the character, attitude, self vs others, self vs society, etc. They are imbibed through beyond curricular activities such as industrial visits, guest lectures, seminars, projects, workshops, hackathons, competitions, etc. All have profound impact and lead to desired transformations in students broadly covered under POs, like teamwork, communication, ethics, finance, life-long learning, etc. Suitable weightage can be provided accordingly for all the activities.

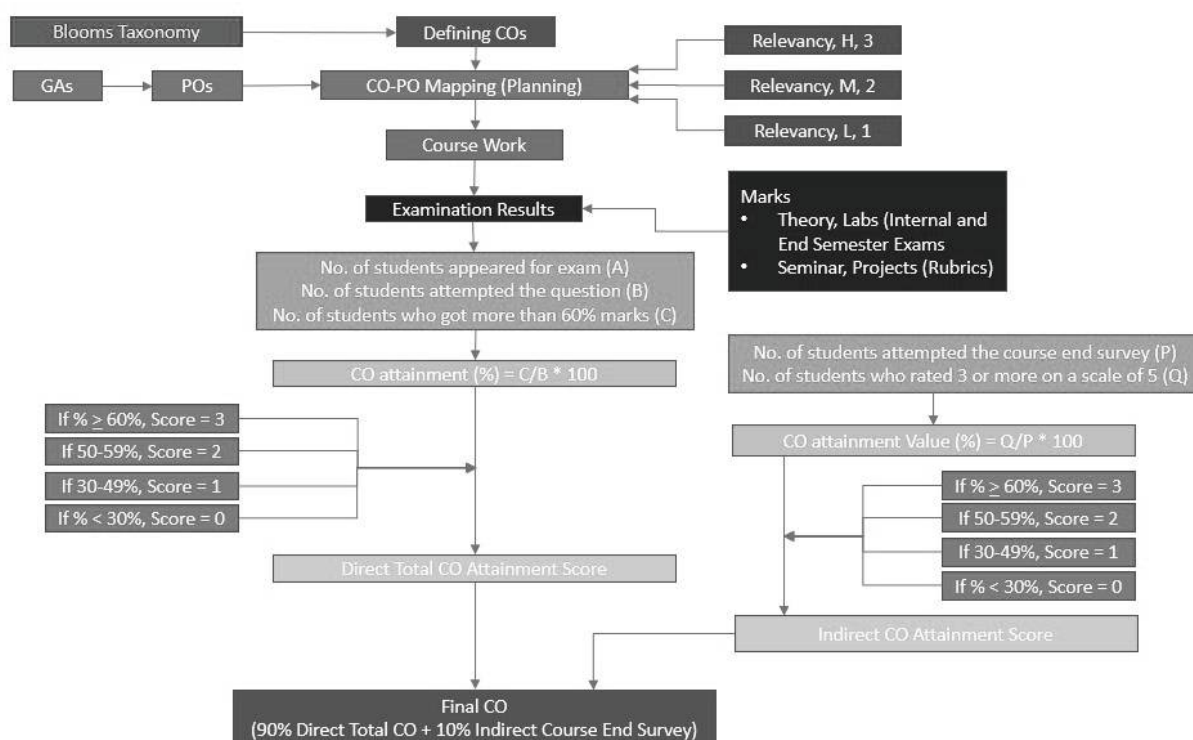


Fig. 6: Flow chart to calculate CO

#### 4. Attainment of PO

A program will have multiple courses for which attainment will be calculated. Combining all of them through CO-PO mapping, attainment for the program is evaluated to identify the level of transformation of the student at the end of the program in terms of the attitude, skills and knowledge.

To illustrate the process of PO attainment, the following arbitrary values are taken as an example as shown in Fig. 7 which consists of percentage of students who crossed threshold value and the relevant score values. With the final CO attainments of all the outcomes calculate the sum. For each course multiply the final CO attainment value with CO-PO mapping relevance value of 3, 2 or 1 and divide with total number of relevant COs normalized on a scale of 3. Fig. 8 shows the PO attainment for a course obtained from the CO-PO mapping and the relevant CO attainment values.

PO attainment is calculated as shown in Fig. 9 for all the courses and added together to obtain the final PO. As in case of CO attainments, PO attainments also consider the weightage for direct and indirect methods. Indirect assessment relies on the program exit feedback taken from the outgoing students for each program provided on all the aspects of attitude, skill and knowledge. Final PO attainment can be consolidated as 90% of direct and 10% of indirect.

| Course Outcomes | % of students crossed threshold value | Score |
|-----------------|---------------------------------------|-------|
| CO1             | 55.83                                 | 2     |
| CO2             | 74.56                                 | 3     |
| CO3             | 58.23                                 | 2     |
| CO4             | 69.89                                 | 3     |
| CO5             | 81.21                                 | 3     |
| CO6             | 50.67                                 | 2     |
| CO7             | 82.45                                 | 3     |

Fig. 7: Percentage of students crossed threshold value

| Couse Code            | Program Outcomes |             |             |             |             |              |             |             |          |             |             |          |
|-----------------------|------------------|-------------|-------------|-------------|-------------|--------------|-------------|-------------|----------|-------------|-------------|----------|
| Course Outcomes       | a                | b           | c           | d           | e           | f            | g           | h           | i        | j           | k           | L        |
| CO1                   | 2                | 1.33        | 1.33        |             |             |              |             |             | 1.33     |             |             |          |
| CO2                   | 2                | 3           |             |             |             |              | 2           |             |          |             |             | 2        |
| CO3                   | 1.33             | 2           |             | 2           |             |              |             |             |          |             |             |          |
| CO4                   |                  | 3           | 2           |             |             |              | 2           | 1           |          |             |             | 2        |
| CO5                   |                  | 2           | 3           |             |             |              | 2           |             |          |             |             | 2        |
| CO6                   | 1.33             |             |             | 1.33        | 1.33        | 0.67         |             |             |          | 1.33        |             | 2        |
| CO7                   |                  |             | 3           | 2           |             | 2            | 2           |             | 2.00     |             |             |          |
| <b>PO (Execution)</b> | <b>1.67</b>      | <b>2.27</b> | <b>2.33</b> | <b>1.78</b> | <b>1.67</b> | <b>2.083</b> | <b>1.67</b> | <b>1.33</b> | <b>2</b> | <b>1.67</b> | <b>1.33</b> | <b>2</b> |

Fig. 8: CO-PO (Execution)

Final PO =

90% Total PO + 10% Program Exit survey

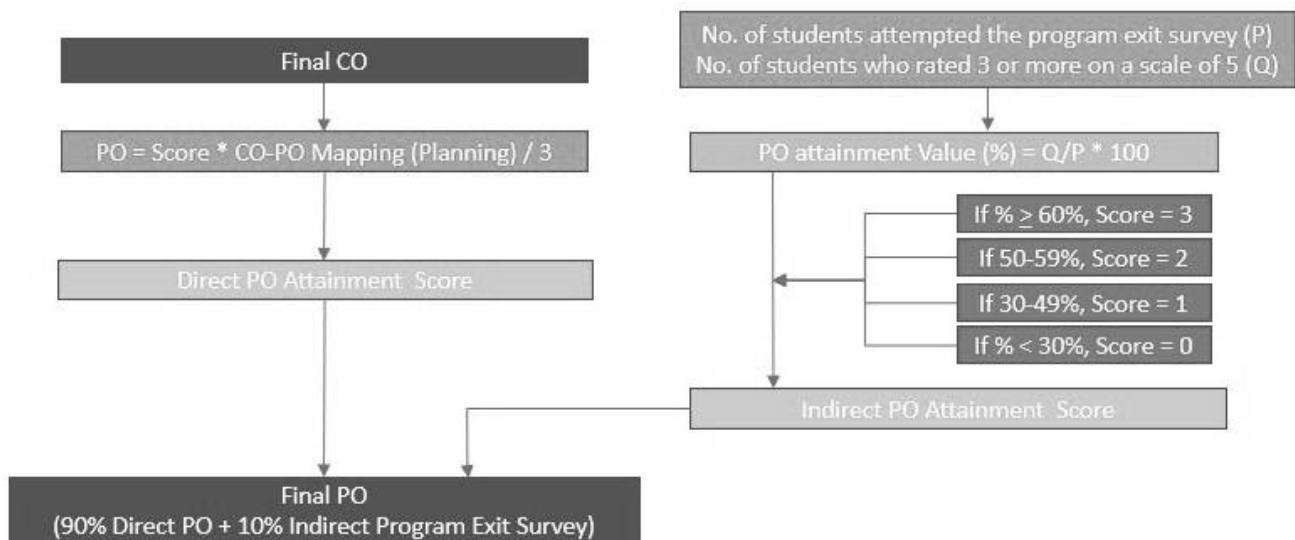


Fig. 9: Flow chart to calculate PO

## 5. Validation of CO and PO Attainment

All the course outcomes must be assessed and the respective CO attainment values are measured. If the attainment of any CO does not satisfy the requirements of threshold value, then suitable remedial actions must be taken so as to improve them through appropriate teaching-learning activities for the ongoing cohort as well as for the future cohorts. Based on the analysis done through various assessments methods, question paper patterns, internal marks, external marks, attainments, attempt percentage, etc., the threshold value for attempt, for the marks, relevance scale bands need to be reviewed and revised periodically so that expectation bars or the targets can be raised, in order to improve quality. PO planning and PO execution is compared as shown in Fig. 10 to analyse the values for a course.

| Name of the Course | PO        | a    | b    | c    | d    | e    | f | g    | h | i    | j    | k    | l |
|--------------------|-----------|------|------|------|------|------|---|------|---|------|------|------|---|
|                    | Planning  | 2.25 | 2.6  | 2.5  | 2.33 | 2    | 2 | 1    |   | 2    | 2    | 2.25 |   |
|                    | Execution | 1.67 | 2.27 | 2.33 | 1.78 | 1.67 | 2 | 0.83 |   | 1.67 | 1.33 | 2    |   |

Fig. 10: PO Actual vs PO Attained

Taking into account all the courses of the program, similar procedure is followed to summarize the final PO attainment. Accordingly, suitable remedial actions such as tutorials, guest lectures, seminars with industry experts and other beyond curricular activities may be planned to enhance and strengthen at program level. Also, if required course outcomes and content can also be revised.

## 6. Conclusions

Mission accomplishment through objective oriented programs consisting of courses and learning activities has been the endeavour of any institution. Program educational objectives can be considered to be wholly achieved only if transformation is evident in all the vital aspects of attitude, skills and knowledge and it is widely accepted that all these aspects can be measured in OBE through the attainment process of course outcomes and program outcomes.

The proposed methodology calculates the attainment at course level and at program level. This also gives an evidence of mapping between course outcomes and program outcomes indicating the significance of program educational objectives. The process of taking first class as threshold value is a reasonable recommended target to measure the attainment of CO and PO for both direct and indirect methods.

The course outcomes could be better achieved with the various teaching methodologies, learning activities and remedial measures. Constant review and revision of assessment methods, threshold values, outcomes and remedial measures boosts the implementation of OBE to improve the quality of learning and student success. Outcome based education thus helps to identify the level of transformation of the student who is intended to be universally acceptable and useful for the society.

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# Active Learning Techniques for Effective Online Teaching and Learning in Higher Education

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**Abstract :** This article proposes active learning strategies for delivering engineering courses to the students in order to make learning more engaging, interesting, accomplishing, and joyful. The education system was impacted by the unprecedented situations generated by the Coronavirus pandemic from the last two academic years. The student community is also going through difficult situations on many levels. The primary challenge for teachers was to engage the students passionately in learning while maintaining a stress-free, healthy and fruitful environment in the online classes. For a stress-free teaching-learning process, adopting a variability in course content delivery methods would be a smart choice for teachers. This paper discusses the most effective active learning strategies in higher education. The work also highlights examples of implementation and an analysis of the effectiveness of active learning methodologies in terms of learners understanding, competency, satisfaction and knowledge gain. The findings indicate that the active learning strategy has assisted students in being more comfortable and engaged in effective learning in the online mode.

**Keywords :** Active Teaching and Learning; Crossword; Higher Education; Mind map; Project Based Learning; Think pair share.

## 1. Introduction

In earlier days teacher's role was to explain the concept using common techniques called chalk and board, and reading books. Keeping students engaged for complete one hour in the classroom is a challenging job for teachers. Normally if a class is having 40 or more than 40 students then this regular teaching learning technique may become fruitful for 50% students only. Also it has been observed that the actual listening span of a student is for maximum 30 minutes. After that students cannot give 100% attention and even a teacher explains the concept, 50% students will not grasp it. Again after next 15 minutes, 75% students will not give their attention in class.

In recent years, teachers are using various teaching aids like power point presentation, animations, videos and reference papers which helps to make the class more interactive and to increase student involvement (Sameer et.al., 2014). Up to some extent students' response seems to be worthy, as the contents reflected in power point are in numerous form with colorful images, diagrams, and colorful text. As technology trends are increasing drastically, experts are preparing videos either by explaining concepts in easy manner, or by creating animated videos and audio-visual

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concept explanation. In this way, teachers are using these video clips as per their requirement and explaining the concept to the students. So instead of listening to teacher only, if in between different teaching aids are used then students' curiosity will increase towards learning.

Along with these teaching aids, now a days' all teachers are using various active learning methodologies to explain the concept in more interactive way. The active learning methods commonly used are Project based learning (PBL), Problem based learning, Think-Pair-Share, Flipped classroom, Mindmap, Jigsaw, Role play, Instant Quiz, etc. These tools focusses more on the technical concept. Gamification activities are widely being used by teachers, as almost all students attracts quickly and easily towards games. It has been observed that gaming activities becomes helpful to resolve common classroom issues like individual student participation, team work, talk time of instructor, opportunity to express, and explain the result. Gamification activities helps instructor to explain the concept from theory to practice and teacher becomes facilitator. Well known gamification activities which can be explored in teaching and learning are Crossword, Millionaire, Cryptex, Snake and Ladder, Scavenger hunts, bingo, dice games etc.

In current pandemic situation, the drastic change is reflected in teaching and learning process. With the help of various meeting platforms like Zoom, Google Meet, Webex, Microsoft Teams, GoTo Meet etc. students and teachers are communicating. Teachers and students are facing new challenges in an Online Teaching Learning (OTL) mode, and to fulfill the requirement, teachers are adopting new, interesting and innovative online teaching learning schemes. However, every coin is having two faces. The online teaching offer immense flexibility and a greater scope for interaction with and participation by the students. Also this strategy saves precious travelling time, money, and energy which was often the adverse situation for many students (Benta et.al., 2014). In addition to pre-recorded lectures, Short and on-the-spot quizzes, Discussion Forum, slot booking feature for doubt clearing as per student time, and concept-strengthening classes becomes an integral part of online teaching. To inculcate these features, to strengthen the execution of all required activities and to complete assessment, various Learning Management Systems (LMS) and Course

Management System (CMS) platforms (Ninoriya et.al., 2011) are being used like Moodle, Canvas, Claroline, MyGuru2, Google Classroom, Schoology, Blackboard, Edmodo, Bodhi Tree and SAFE Tools offered by IIT Bombay etc.

Section II explores the literature review on active learning methodologies used to explain the concepts from various courses. Section III describes five methodologies, Project Based Learning, Crossword Puzzle, think pair share, Quizzes and Polls, and Mind map which can be used to improve student engagement in the class. In section IV, the results after using various Active learning methods and Gamification methods have been presented which contribute lot to enhance student engagement in subjects like Digital Electronics, Basic Electronics and Electrical Engineering, Coding Techniques, Analog Communication, Internet of Things and Microcontrollers course of Electronics and Communication Engineering program.

## 1. Literature Survey

The COVID-19 outbreak forced to convert from traditional face-to-face teaching to an online format. An observational research in which faculty members and students from engineering completed survey and answered quantitative and qualitative questions to highlight the challenges they faced during online education. Study revealed a number of difficulties that have a detrimental impact on online engineering education, including logistical and technological challenges (Asgari et.al., 2021).

Claudiu Coman et al., 2020, discussed the impact of E-learning on the educational process and students' perceptions of using the online environment in the teaching and learning process. E-learning using online platforms like Moodle, helps lot for smooth delivery of online lectures, student-teacher contact and cooperation, web conferences, and chat. In order to develop and strengthen the E-learning system during Covid-19, they analyzed the student's perspectives by sending a Google form on Facebook with a few questionnaires.

The pandemic situation had moved us to make the teaching and learning process online and student-centered in which students can actively learn about a subject. To accomplish this, many new innovative methods have been adopted by various universities. The aim is to use these innovations approaches to

make the learning process more engaging and dynamic, encouraging students to participate actively in these innovations (Mohammed et.al., 2011).

For courses like Analog communication, Signals and Systems, and electromagnetics, active learning strategies like think-pair-share, turn and talk, Jigsaw are effective because they require a lot of basic principles to be retained (Sridevi Chitti et. al., 2020). Active learning technique like buzz activity through poster presentation, games, animated movies, and simulation tools is used to address the difficult problem of student involvement in learning (Snehal S. Patil et. al., 2020).

Several collaborative learning methods like Role play, Think Pair share, Jigsaw and Concept Map (Manju et.al., 2018) are used for effective teaching and learning. These methods helps to increase student engagement in the classroom as they focuses more on practical approach. Teachers are encouraged to use their professional judgement to review the suggested innovative teaching tools and decide on the most appropriate for meeting the needs of their students and deliver the essential content. As teachers know their students learning styles and needs, they can select numerous interesting strategies or adapt those suggested to deliver the content (Misseyanni, 2018).

Through formal and informal interaction with students, teachers build an educational environment that determines what students feel about learning. This has a significant impact on students' learning (Biggs et.al., 2011).

As result of online learning, the student-teacher connection becomes less intimate. Educators are required to transform the classroom into an online learning environment. What precisely does a teacher need to do to encourage students in an online environment? (Picar, 2004).

## **2. Methodology**

Encouraging students to take a more active role in their own education is becoming influential. The focus is on learning, therefore instructors must include more active and student-centered learning approaches during course content delivery. More active the students are in the classroom, the more engaged they are in the learning process, and the more they utilize concepts in real application.

### **A. Project Based Learning**

Project Based Learning (PBL) is a student-centered pedagogy that incorporates an active learning approach wherein students are encouraged to actively explore real-world issues and problems in order to get a better understanding. Across many educational disciplines, problem-based learning has proven to be a very effective pedagogical paradigm. The first step in PBL is to assign tasks that will lead to design prototype or the development of a final product or object. Students examine the issues and come up with remedies. Students create a solution prototype by designing and developing it. One of the positives of using PBL is the student involvement in their own learning. It empowers learners to pursue their own interests and ways to address the issue that have been posed. A multidisciplinary project-based teaching learning approach can help students to improve the employment skills.

### **B. Crosswords Puzzle**

Crossword puzzle game activity helps to make learning more enjoyable. It allows students to be more engaged in the learning process by giving them a recreational break during the lectures. Students can access and review the course material notes to solve the puzzles. Cross word puzzles helps students to remember, recall and understand the keywords. This active learning approach helps learners in improving the Lower Order Thinking Skills (LOTS). This activity is an enjoyable and recreational activity, helps to change study habits and skills, and create interest in the course contents (Crossman 1983).

### **C. Think Pair Share**

Think Pair Share (TPS) is a collaborative learning method in which students work together to solve a problem or answer a question about a learning segment. This approach needs students to first think independently about a topic or answer to a question; and then share thoughts with classmates (Sharma et. al., 2019). Discussing with a partner maximizes participation, focuses attention and engages students in comprehending the reading material. It helps students to think individually about a topic or answer to question. It teaches students to share ideas with classmates and builds oral communication skills.

#### D. Think aloud (Quizzes and Polls)

The think-aloud strategy asks students to say out loud what they are thinking about when solving problems, or express out by responding to questions posed by teachers or other students. This approach may be used to fetch student attention and engagement in the classroom.

Taking quizzes and polls during teaching is a popular activity. It helps to keep students engaged in a class. After explaining the particular concept in class, teacher has to float simple question based on that topic. Teacher has to think always about how to make the class interactive. As in traditional classroom teaching, teacher was teaching and learners' job was to listen, take the notes, and grasp the concepts. To increase the attention span of student in online teaching mode, quizzes and polls contribute lot. The learning platforms which offers various game activities, quiz types and polls are Kahoot, Mentimeter, Class Dojo, Factile, Flipgrid and Slido etc. These learning platforms, really brings magic in learning to the students.

#### E. Mind Map

Mind Map is an innovative activity which enables students to think on particular topic, encourages a free flow of ideas and put the contents in chart form. Mind mapping is a influential practice that helps to imagine the concept, visualize the thoughts and communicate them to others. This activity also motivate student to sketch and represent the contents in free hand and with free mind. Given topic is broken in number of pieces or blocks and then represented in terms of drawing such that collectively it reflects the whole theme of the topic. Mind Map is a graphical representation of concept that convey the relationship between individual ideas and concepts. Students and teachers are using Mind Map activity for immediate note taking, project planning, and complex concept explanation. Mind map becomes an attractive and beneficial learning tool to help to brainstorm any topic, increase student performance, Incite critical analytical thinking, and think creatively (Abdurrahman et.al., 2015). Mind maps are often very beneficial in the writing process as it allows students to think about a topic or theme in a natural way.

### 3. Implementation And Results

This work recommends an active learning strategy

for delivering engineering courses to learners to make electronics more engaging. PBL is one of the assessment tools used for the first year engineering students to explore Basic Electronics and Electrical Engineering course for continuous laboratory evaluation.

At the start of the semester, students were given an option of selecting open-ended design projects based on their interests. Pandemic conditions have shifted education to online mode. The majority of the students used an online circuit simulator to develop and build their designs. Few students were able to manage hardware components and actual implementation.

There was a lack of companionship and interaction among students as a result of widespread usage of online learning methods. Through the PBL activity, students were able to get to know each other more and collaborated on a project from different locations (Kenesha et. al., 2016).

Making the PBL activity a requirement in the course assessment rather than an optional, helped to foster participation of all the students. During the assessment process, everyone gets the opportunity to share his or her thoughts and ideas about the project. Evaluation of students done based on their design and synthesis abilities. Fig 1 shows the sample for the project titled single axis solar tracker system implemented using online circuit simulator like Tinker Cad.

The students' opinion towards the PBL activity (5-point Likert scale, where 1 represents towards a very small level, 5 denotes to a very great level) is collected for various courses.

Fig 2 indicates the feedback analysis for the first year engineering course on Basic Electronics and Electrical Engineering for PBL Active Learning

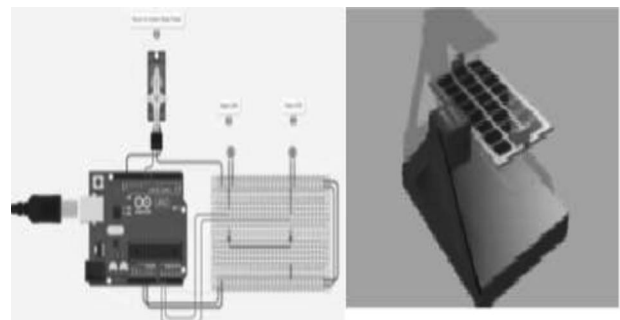


**Fig. 1 : Single Axis Solar Tracker Project**

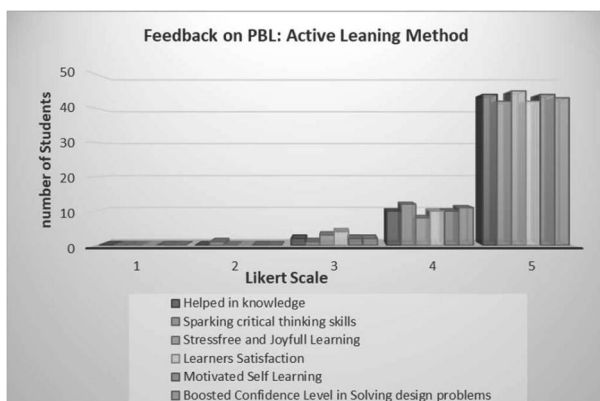
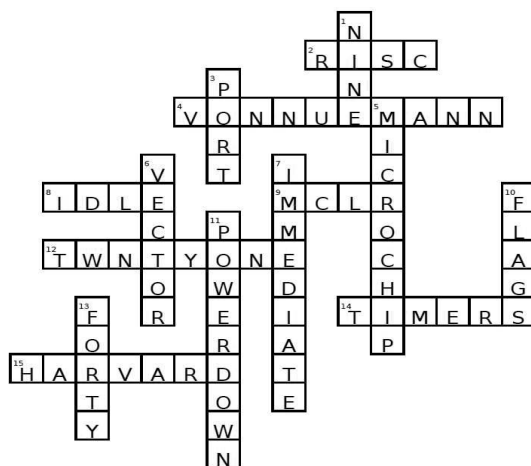


**Fig. 2 : Feedback from Learners on PBL Activity**

Technique. As reflected from the feedback analysis, 95% students from the class supports this activity positively as they have scaled it to 5 point.

Crossword puzzle is an interesting gamification activity which helps to increase student active participation and involvement. After completion of module from the course syllabus this technique is used to understand the learning level of students.

Few courses like Microcontrollers, Internet of Things (IoT), Coding Techniques need students to memories a significant number of important terms or specified points, as memorizing and retaining the



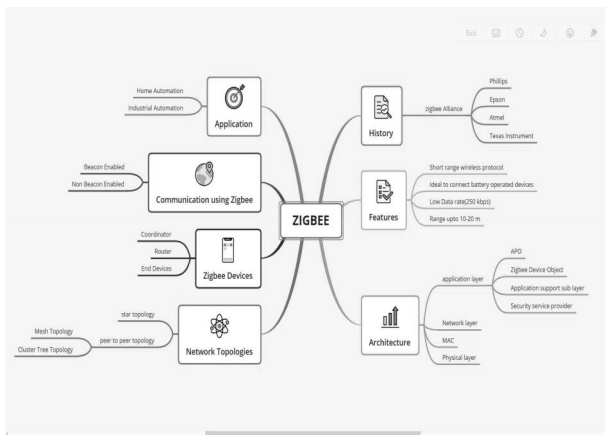


Fig. 4a. Mindmap (Wireless Technology)

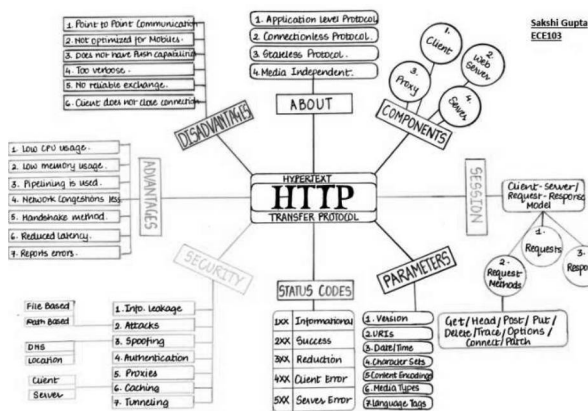


Fig. 4b. Mindmap (IoT Protocol)

Fig. 4a and 4b. Sample Mindmaps

Mind Map shown in Fig. 4a. reflects the concepts related to ZigBee protocol and the sketch is drawn using XMind online Application and Fig. 4b. displays the Mind map with freehand sketch drawn for HTTP protocol. This activity is executed for the topic wireless techniques and protocols of IoT. Students have selected the techniques as per their choice and interest. Many students created mind maps using online software like XMind and MindMeister, while other students used free hand drawing to complete the task. This activity really captivated students, as they gained access to a platform that allowed them to represent ideas in graphical form without restriction.

Fig. 5a and 5b. represents the quizzes conducted during the lecture and response collected from students using Mentimeter. Fig. 5a. is the word cloud type of response received from Final year students for Internet of Things course. Fig. 5b. is the response for multiple choice question in bar chart format for Third year students conducted for coding Techniques course.

1. Name the hardware platforms that you used for IoT based Projects

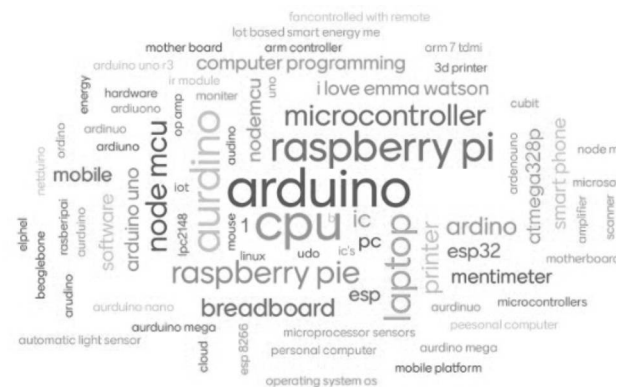


Fig. 5a. Word Cloud

2. Which coding technique has memory? Fig. 5b. Multiple Choice with Bar chart

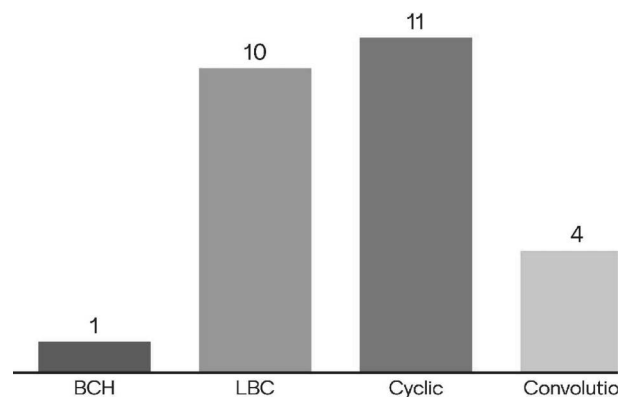


Fig. 5b. Multiple Choice with Bar chart

3. Non coherent detection technique requires the knowledge of transmitted carrier frequency and phase at the receiver.

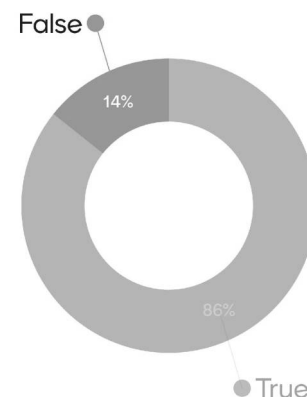
Fig. 5c. Multiple choice with Donut  
Fig. 5a, 5b and 5c. Quizzes

Fig. 5c. shows the student answers in Donut format for Analog Communication course. This is one of the interesting activity which helps to keep students engaged and alert in class. Joyful learning with Mentimeter helps to increase student involvement and attentiveness in the class. Using this platform, teacher can conduct quizzes and take polls by asking questions and collect the answers in different forms like word cloud, multiple choice, open ended, Q&A, Select answer, Type answer etc.

The instructor had to deal with a significant number of students with varying levels of prior experience and initial knowledge. Additional constraints in online teaching include logistical/technical problems, insufficient hands-on training, lack of engagement in classes, difficulty maintaining focus, and fatigue from Zoom. Think Pair Share active learning activity was beneficial to address these challenges. TPS exercises, helped the majority of students to enhance their conceptual knowledge (Kothiyal, et.al., 2014). Digital electronics is a mandatory course for all electronics, electrical, and computer engineering majors. TPS tool is used in course content delivery for various digital design concepts and mini projects.

**Table 1 :**  
**Sample For Tps Activity For Digital Electronics Course**

|                                                             |                                                               |                                                                                                                             |                                                                                |
|-------------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Read the Given Design Problem Statement                     | What is my response to design problem?                        | What does my partner think?                                                                                                 | What will we share?                                                            |
| Design a code converter that converts BCD to Excess-3 code. | Design approach is to minimize number of gates in the circuit | Design approach is to minimize the number of ICs. Discuss, compare individual design and come up with best design solution. | Share the design solution having the optimized power and hardware requirement. |

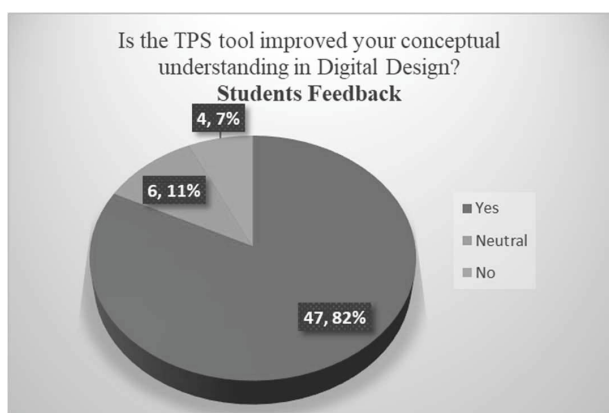


**Fig. 6. Students Feedback on TPS activity**

Various learning modules are planned into design problems for students to “Think” about it and try to devise a solution on their own, and then discuss their ideas with partners for getting best solution, and share the solution with whole class. Table 1 shows the sample of design problem taught in the class for the course of Digital Electronics using TPS. TPS appears to have helped in the development of logical and conceptual design skills, as well as the development of a higher order skill set in learners, as revealed by the student's results and feedback. Fig. 6. shows the feedback from the class of 60 students for the TPS tool used during course delivery.

There are a few challenges in implementing active learning methodologies in the online mode which includes technical issues like power outages, poor internet connectivity, and robust E-learning platforms.

One of the challenges in active learning methodology implementation is educators' readiness to adapt to changes in traditional teaching methods and influencing students' views about online learning.

Teachers needs to put in extra effort to design activities, which requires strong technical expertise of course contents, a creative mindset, skills in execution and assessment.

For evaluating efficacy of the activities, feedback data is collected online. The feedback form was sent as a link on the google classroom through the google forms, during the first, second and third trimester of the 2020–2021 academic year.

Table 2 showcases the cumulative feedback from students on the usage of active learning methods used

**Table 2 :**  
**Cumulative Feedback on Active Learning Methodologies**

| Methodology Used                            | Performance Parameters                   | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---------------------------------------------|------------------------------------------|-------------------|----------|---------|-------|----------------|
| PBL, Cross-Word, Think Aloud, TPS, Mind Map | Learners Understanding Level improvement | 1                 | 3        | 9       | 47    | 120            |
|                                             | Learners competence level boosted        | 1                 | 3        | 9       | 49    | 118            |
|                                             | Learners confidence level increased      | 1                 | 3        | 10      | 45    | 121            |
|                                             | Learners Satisfaction Level Increased    | 1                 | 3        | 11      | 50    | 115            |
|                                             | Learners Enjoyed Activities              | 1                 | 3        | 8       | 46    | 122            |
|                                             | Learners Performance Boosting            | 2                 | 3        | 8       | 47    | 120            |

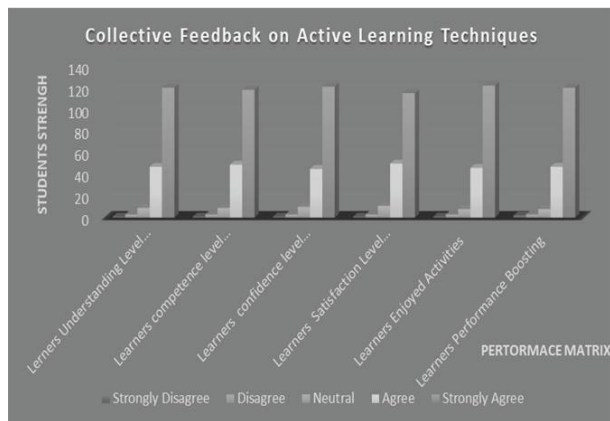


**Fig. 7 : Collective Feedback from Learners on Active Learning Techniques**

in three trimesters for the academic year 2020-21. COVID-19 forced a global and abrupt conversion of traditional face-to-face instruction to online instruction in the academic year 2020-21.

Collective feedback analysis shown in Fig. 7. reflects that 93% students have confirmed that they are getting benefits with active leaning methodologies.

## 5. Conclusion

This paper explores our experience in implementing active learning techniques to develop and teach a courses like Microcontrollers, Digital Electronics, Analog Communication, Coding Techniques and Internet of Things to the undergraduate engineering students. A new approach of integrating PBL with the University's assessment model has been developed, executed, and assessed for several courses in the Electronics and Communication Engineering. Students' responses and analysis demonstrate that the adoption of active learning strategies benefited 93 % of students by enhancing their interest, grades, basic understanding and drive for self-directed learning. Employers always look for important abilities in students such as responsibility, creative thinking, deadline sensitivity, resource management, team work, presentation skill, and logical decision-making. These skills are enhanced by active learning methodologies used during course delivery and assessment. Learning really happens in the online and offline classrooms, when teachers adopt effective planning and active learning strategies in teaching. In view of both students' feedback and the attainment level of course objectives, we can conclude that active learning strategies are effective and useful in Teaching and Learning for higher education.

## Acknowledgment

We appreciate the students for the enthusiastic involvement, insightful feedback in reviewing the success of implemented active learning methodologies. We are also grateful to the School of Electronics and Communication Engineering, MIT World Peace University for inspiring us to use active learning techniques and giving the required platform and support.

**Leave this section as is for the double-blind review process.**

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# Digital Education Challenges and Opportunities

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**Abstract :** Online education is existing since 2014 but it becomes the only mode of instruction in 2020 due to the Covid pandemic. The whole world faces a lot of challenges, especially in developing countries. It is because in developing countries technology is confined to metropolitan cities only. A major portion of these countries are still rural and cannot provide the necessary infrastructure for digital education. Even after these challenges, it brings manifold opportunities too. This paper will study the opportunities and challenges faced while providing education in Online Mode from the perspective of students, teachers, and education Institutes/Universities.

**Keywords :** Digital Education, Online education, Covid-19, Challenges, Opportunities, Recommendations

## 1. Introduction

Online Education is internet-based education that relies on the internet and other electronic instruments (Computer, Mobile, Tab, Radio, TV, etc.) for interaction and communication between the teacher and students. It can also be termed e-learning, computer-based education, web-based learning, distance education, etc. Online education was initially conceptualized in asynchronous mode from Boston in 1728 through weekly letters. In 1922 the courses are broadcasted on radio as World War one opened opportunities for broadcasting. In 1953, television was used as the medium of education at the University of Houston. The origination of the internet and the World Wide Web opens up new prospects for universities and educational institutes for online education. In 1996 duke University started its first executive MBA program globally. In 2008 first MOOC (Massive Online Open Course) [1] was created and in 2012 Coursera, Udacity, and edX were also launched.

The government of India has also taken many initiatives under the digital-India campaign to promote digital education. These are SWAYAM (Study Webs of Active Learning for Young Aspiring Minds), DIKSHA, e-PG Pathshaala, Swayam Prabha, National Digital Library of India (NDLI), E-Shod Sindhu, National Programme on Technology Enhanced Learning (NPTEL), Virtual Labs, etc.

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Technology is growing exponentially in the 21st century which influenced almost every sector. As per the Economic Times report, the number of internet users will increase by 40% and Smartphone users will be doubled by 2023. Universities are offering one of the courses through the digital domain only. They provide interactive learning models to attract learners. Institutes are gradually introducing digital practices. They have updated their curriculum to introduce new

technologies so that they can deal with modern businesses [2]. Universities and Educational Institutes are shifting from traditional teaching to new age methodologies which are using the current technologies like IOT, Clouds, robotics, nanotechnology, etc. Moreover, many start-ups are coming forward to this sector which further changed the emplacement dynamics too.

**Table : Literature Review**

| Authors    | Year |                                                                                                                                                                                                                                                                         | Literature Study                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                  |
|------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |      | Study                                                                                                                                                                                                                                                                   | Perspective of teachers                                                                                                                                                                                                                                                            | Perspective of Students                                                                                                                                                                                                                                                         | The perspective of Educational Institutes/Universities                                                                                                                                                                                           |
| Challenges |      |                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                  |
| [2]        | 2020 | This study is conducted o investigate the online strategies in Iran to improve the Quality of digital education                                                                                                                                                         | <ul style="list-style-type: none"><li>• Become difficult to satisfy the students due to lack of human touch.</li></ul>                                                                                                                                                             | <ul style="list-style-type: none"><li>• Dissatisfaction and confusion due to lack of human touch</li></ul>                                                                                                                                                                      | <ul style="list-style-type: none"><li>• Prmatue shift to online mode of education due to Covid-19 outbreak</li><li>• Overloading of servers due to large scales users shifts from online to offline mode.</li></ul>                              |
| [3]        | 2020 | This study has been conducted in Slovakia on Chemistry Secondary school teachers and students. The teachers used in this study are fully trained and equipped with ICT tools. Their experiences are recorded for digital education                                      | <ul style="list-style-type: none"><li>• Even after training, teachers need regular assistance.</li><li>• They face problems to meet Student Expectations</li></ul>                                                                                                                 | <ul style="list-style-type: none"><li>• Students face trouble due to slow internet connection So not able to attend high-Quality videos and meetings.</li><li>• 33% of students reported problems regarding the speed of lectures and understanding online materials.</li></ul> | <ul style="list-style-type: none"><li>• Provide regular training, support, and assistance.</li></ul>                                                                                                                                             |
| [4]        | 2009 | In this study, it has been found that Online nursing exhibits unique challenges, such as providing nursing students with online<br><br>authentic learning experiences that relate to real-world nursing situations,                                                     | <ul style="list-style-type: none"><li>• Need Sufficient time to develop Courses</li><li>• Don't have sufficient Infrastructure</li></ul>                                                                                                                                           | <ul style="list-style-type: none"><li>• Difficult to have real-life experiences as required in nursing education</li></ul>                                                                                                                                                      | <ul style="list-style-type: none"><li>• All organizations are cannot afford to provide/maintain the necessary infrastructure that is required for Nursing education</li></ul>                                                                    |
| [5]        | 2014 | As per the author, Online teaching cannot be used as an alternative to traditional learning. This is because Soft skill training requires interacting with real people to improve performance. The trainer can collect genuine feedback which helps him for progression | <ul style="list-style-type: none"><li>• Slow internet connection</li><li>• The faculty/instructor is that they have to restructure the classes which consume an adequate amount of time.</li><li>• Frustrated and confused learners exhibit resistance in the classroom.</li></ul> | <ul style="list-style-type: none"><li>• No Standard e-learning content is available</li><li>• Slow internet connection</li><li>• No Social Interaction</li><li>• Learners have a low level of engagement</li></ul>                                                              | <ul style="list-style-type: none"><li>• E-learning requires certain technical infrastructure that cannot be afforded by every participant/organization</li><li>• An effective evaluation strategy is required especially in e-learning</li></ul> |

|                      |      |                                                                                                                                                                                              |                                                                                                                                                                                                                                      |                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                      |
|----------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [6]                  | 2018 | The authors have conducted a study in India and discuss various driving factors, opportunities, and challenges faced by online education                                                     | <ul style="list-style-type: none"> <li>• Limited Social interaction</li> <li>• Lack of motivation</li> </ul>                                                                                                                         | <ul style="list-style-type: none"> <li>• Limited Social interaction</li> <li>• Language Barrier</li> </ul>                                                                                                               | <ul style="list-style-type: none"> <li>• Insufficient digital infrastructure</li> <li>• Questionable credibility of degrees</li> </ul>                                                                                                               |
| [7]                  | 2020 | This study has been conducted in Zambia to investigate the mathematics teachers perspective in online teaching during                                                                        | <ul style="list-style-type: none"> <li>• Unstable Electricity and internet connection</li> <li>• High internet cost</li> <li>• Unfamiliar technology</li> <li>• Skill and attitude to use online platforms and technology</li> </ul> | <ul style="list-style-type: none"> <li>• Unstable Electricity and internet connection</li> <li>• High internet cost</li> <li>• Unfamiliar technology</li> </ul>                                                          | <ul style="list-style-type: none"> <li>• Ensure every student and teacher has the facility to join online education.</li> <li>• It should be part of the curriculum even before and after the pandemic.</li> </ul>                                   |
| [8]                  | 2020 | This study has been conducted by the Education faculties of the Open University of Sri Lanka. The purpose of this project is to promote (C-DELTA) program in Secondary schools in Sri Lanka. | <ul style="list-style-type: none"> <li>• Slow Internet connectivity</li> <li>• Language Barrier</li> </ul>                                                                                                                           | <ul style="list-style-type: none"> <li>• Poor Internet connectivity</li> <li>• Poor motivation</li> </ul>                                                                                                                | <ul style="list-style-type: none"> <li>• Lack of Infrastructure</li> </ul>                                                                                                                                                                           |
| <b>Opportunities</b> |      |                                                                                                                                                                                              |                                                                                                                                                                                                                                      |                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                      |
| [9]                  | 2018 | In this paper, the study is conducted in developing nations and found that it has positively impacted on health education against the infectious diseases                                    | <ul style="list-style-type: none"> <li>• Positive impact on health due to presence of infectious diseases</li> </ul>                                                                                                                 | <ul style="list-style-type: none"> <li>• Reduced Cost</li> <li>• Increased access to content</li> <li>• Positive impact on health due to presence of infectious diseases</li> </ul>                                      | <ul style="list-style-type: none"> <li>• Reduced Cost</li> </ul>                                                                                                                                                                                     |
| [5]                  | 2014 | As per the study, even traditional classroom teachings have no alternate. Even then companies are motivated for online training because of cost-effectiveness and ease of deployment.        | <ul style="list-style-type: none"> <li>• In traditional teaching, the teacher has to spend most of the time controlling the class. Now he can focus on teaching only</li> </ul>                                                      | <ul style="list-style-type: none"> <li>• Flexibility of learning</li> <li>• Cost-effective</li> <li>• Immediate transfer of knowledge when required</li> <li>• Standardized training irrespective of location</li> </ul> | <ul style="list-style-type: none"> <li>• Cost-effective</li> <li>• ease of deployment of e-learning to implement technology-based training</li> <li>• Quick start and wind up of e-learning courses. So companies save 20% to 60% of time</li> </ul> |
| [6]                  | 2018 | The authors have conducted a study in India and discuss various driving factors, opportunities, and challenges faced by online education                                                     | <ul style="list-style-type: none"> <li>• Motivates to use Blended model in future</li> </ul>                                                                                                                                         | <ul style="list-style-type: none"> <li>• Access to E-Learning through mobile phones are increasing</li> </ul>                                                                                                            | <ul style="list-style-type: none"> <li>• New courses are coming into the picture as per the demand i.e. Cloud computing, Big data, IoT, etc.</li> <li>• No of the industries coming into the E-Education market</li> </ul>                           |
| [10]                 | 2020 | The study presents that how digital learning spaces help in enhanced learning of practical based subjects like art and craft and design                                                      | <ul style="list-style-type: none"> <li>• Teachers are able to better engage the students</li> <li>• They are able to explain it in better way.</li> </ul>                                                                            | <ul style="list-style-type: none"> <li>• In the subject like art, students can experience the real world using virtual reality</li> <li>• In a subject like craft and design, students can</li> </ul>                    | <ul style="list-style-type: none"> <li>• After successfully implementation on two subject these new methodology can be applied to more subjects like Music, Economics and Physical Education subjects etc.</li> </ul>                                |

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|                        |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                               | think and speak using online webinars.                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                   |
| [8]                    | 2020 | This study has been conducted by the Education facilities of the Open University of Shri Lanka. The purpose of this project is to promote (C-DELTA) program in Secondary schools in Shri Lanka.                                                                                                                                                                                                                                                                                                                                                                                                                           | <ul style="list-style-type: none"> <li>• Awareness of digital concepts like Digital Identity and Digital Footprint</li> <li>• Improving digital learning concept mapping</li> <li>• Improved digital educational leadership skills</li> </ul> | <ul style="list-style-type: none"> <li>• Improved digital learning Skills, concept mapping Skills</li> <li>• Gain more confidence experiencing by online learning and online testing</li> </ul>                                                   | <ul style="list-style-type: none"> <li>• After successful implementation of the C-Delta program Educational Institutes are able to add into school curriculum.</li> <li>• Receiving computer and Internet facilities to ICT labs</li> </ul>                                                       |
| <b>Recommendations</b> |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                   |
| [11]                   | 2020 | The study is conducted during the covid-19 outbreak and 5 points are recommended to increase the confidence in e-learning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <ul style="list-style-type: none"> <li>• The instructor needs to be well organized and prepared in advance</li> <li>• A good relation/trust must be established between student and teacher</li> </ul>                                        | <ul style="list-style-type: none"> <li>• Students need to be Self-regulated.</li> <li>• Mental health of Students must be good</li> <li>• A good relation/trust must be established between student and teacher</li> </ul>                        | <ul style="list-style-type: none"> <li>• Course must be taught in chunks</li> <li>• Proper feedback system need to be there to maintain to ensure student satisfaction level.</li> </ul>                                                                                                          |
| [12]                   | 2021 | The author evaluated student persistence in online courses based on various factors. These are anxiety, satisfaction, effort expectancy, engagement, behavioral intention, employer encouragement, facilitating conditions, and performance expectancy. Among which satisfaction, expectancy, engagement, behavioral intention, facilitating conditions, and performance expectancy effects positively on the other hand factors like anxiety and employer encouragement affects adversely on student persistence in online courses. The author considers student anxiety and satisfaction are the most important factors | <ul style="list-style-type: none"> <li>• Instructors need to improve the pedagogy to increase student participation and interaction.</li> </ul>                                                                                               | <ul style="list-style-type: none"> <li>• Students need to be self regulated and they also need to improve their skills by themselves by watching the videos ,reading the tutorials etc.</li> <li>• They need to be fully participative</li> </ul> | <ul style="list-style-type: none"> <li>• Academic institutions can arrange orientation sessions for those students who require skills to attend online courses</li> <li>• LMS should be easy, user friendly.</li> <li>• LMS should contain attractive content to motivate the students</li> </ul> |
| [13]                   | 2006 | The author specifies that Nursing education requires a different approach for teaching practical skills, preparing E-learning materials, and for proper communication with patients and team members.                                                                                                                                                                                                                                                                                                                                                                                                                     | Different pedagogical approach is required so that individual and personalized attention can be provided to each student.                                                                                                                     | <ul style="list-style-type: none"> <li>• Students need to be self regulated</li> </ul>                                                                                                                                                            | <ul style="list-style-type: none"> <li>• Before shifting to a digital approach these points need to be taken care of. Moreover, teachers/tutors must be provided tools with an e-learning environment to manage the lecture material easily and efficiently</li> </ul>                            |
|                        |      | This study has been conducted in most of the countries in the world and it has been found                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <ul style="list-style-type: none"> <li>• Teachers should take care of speed and modulation of voice during online lectures to improve</li> </ul>                                                                                              | <ul style="list-style-type: none"> <li>• Students need to be self-regulated</li> <li>• They need to combine offline self-learning with</li> </ul>                                                                                                 | <ul style="list-style-type: none"> <li>• Preplanning is required</li> <li>• Whole Curriculum must be divided into modules to</li> </ul>                                                                                                                                                           |

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|------|------|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| [2]  | 2020 | despite challenges they supported online education and recommendations have been given to overcome these challenges.          | the grasping power.<br>• Other teaching assistants must be used like WhatsApp and other social media tools to improve the communications                             | online teaching.                                                                                   | increase student focus<br>• Opting new method of teaching<br>• Preparing teachers time to time          |
| [14] | 2020 | This article analyzes how the instructor strategies for designing online discussions affect student participation and grades. | • The instructor should design discussion and grading so that students can involve themselves in a meaningful way so that it can be used for knowledge construction. | • Student need to be participative in class discussions to understand the concepts in a better way | • Online participation should be graded .it should be part of evaluation specially in online education. |

### 3. Challenges In Digital Education

Diverse researches have been reviewed and it has been found most students and teachers faced the same kind of challenges.

1. Internet connection: Major challenge faced by both students and teachers is slow and exorbitant internet connection [3,5,7] which is the backbone of online education. It has been especially faced in non-urban areas of developing countries which results in longer waiting times and ultimately increases student's frustration and confusion.
2. Lack of Infrastructure: There is overloading of servers [2] and deficiency of other necessary infrastructure [3-8] due to premature shift to online education due to covid-19. Moreover, most of the students cannot afford to purchase a desktop/laptop which is a requirement especially for practical/programming subjects for effective online education.
3. Unfamiliar Technology [7] and resistance to change: All the students and teachers are not aware of latest technology. Moreover, technology is changing day by day. Furthermore, there is resistance to change from traditional teaching to online teaching/learning
4. Less Social Interaction [3-6]: Learners have a low level of engagement and interest due to the passive nature of the online lecture. In traditional classrooms, the participants have the opportunity to collaborate, communicate with each other. They can share experiences, problems, support, and friendship [5] which helps them not only in real-life learning but also improves their mental and physical health. This is required for better personal and professional development. This opportunity is not there in online classes. In nursing/medical education [4] where it is required to have good communication between the staff and patients, Social interaction becomes a mandatory requirement.
5. Self-management of Students: In online education there is no direct control of teachers on students so they need to be self-motivated and self-disciplined [6,8]. Parents also play an essential role to make them self disciplined. Moreover proper environment need to be provided during online education so that they can focus on studies.
6. Time: As teachers need to restructure their lectures [4-5] and there is no standard e-content available for online lectures. They need more time to prepare the lecture and materials. So proper preplanning is required.
7. Evaluation and credibility of degrees: In online education, it becomes a challenge to evaluate [5] the students as teachers or Educational Institutes have no direct control over them especially in the scenario of Covid -19. Moreover, there are more chances of fake degrees online so it becomes a question on the credibility of degrees [6].
8. Language Barrier [6, 8]: Online courses can be taught worldwide as well they can reach up to rural areas. But in that case, language becomes an issue if the course is published in a single language

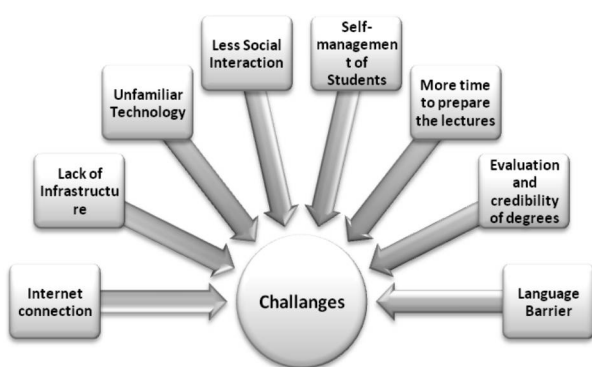


**Fig. 1 : Challenges in Digital Education**

#### 4. Opportunities In Digital Education

Despite of above mentioned challenges the whole world is adopting digital education. This is because of its opportunities i.e. flexibility in learning, cost effectiveness, global exposure, better skills and employability.

1. The flexibility of learning [5,6]: As online education is accessed from the Web, so it is accessible anytime and everywhere where the internet is available. Students need not to travel from long distance to study a course. Moreover, the students who r working or having other liabilities have the opportunity to continue their studies.
2. Cost-effective: Online education is cost-effective [5, 9] because students do not have to pay hostel as well as transport charges. Moreover, there is a lot of free E-content available on the Web. The government is also facilitating for the same so that education can be reached, everyone.
3. Improved skill and confidence [8,10]: There are numerous standardized courses available online and taught by knowledgeable and well-known educators. Now everyone has access to them which was not there in the case of traditional education.
4. Better Employability [5]: Online education act as a medium to bridge the gap between candidates and respective employers. There is an abundance of courses available on advanced technologies in almost every domain i.e. cloud, IoT, Big Data, Software testing, Hospitality, Nursing, Coding, and many more. Students can maintain their skills as per industry expectations.

5. Global Exposure [5]: Many reputed and prestigious institutions all over the world were earlier out of reach. It is because of their admission procedure and unaffordable nature. Now they are offering online courses which are reachable as well as accepted by employers

6. Blended Model [6]: Now a day's blended Model is becoming popular in which students can take benefit from Online learning as well as traditional teaching. Both student and teacher need to be present and online teaching methodologies are blended into traditional methods.

7. Better impact on Health: As teachers and students need not to interact physically so there is no harm from infectious disease. In this way online teaching protects the society from these kinds of diseases.

8. More Productive classes: In traditional classrooms teachers spend most of the classroom time in controlling students. Now in digital learning they can concentrate more on teaching.

#### 5. Recommendations And Conclusion



**Fig. 2 : Opportunities in Digital Education**

As seen from the literature, online teaching cannot replace traditional teaching because cannot ignore the its importance of traditional teaching for development of physical and mental health. Even after the challenges, online education is becoming popular day by day due to the opportunities it is providing to society and it's a need of the hour too. In the case of the pandemic situation, this is the only solution when we cannot compromise the health of students and teachers. But to improve its effectiveness we have overcome most of the challenges discussed in section III. For this we all students, teachers, educational

Institutes, Universities, Industries, and Govt. policymakers have to join our hands and work together to overcome these challenges.

- First and foremost, necessary infrastructure [2,3,8] must be provided because a good Internet speed, necessary equipment is the spine of online education.
- These online courses must be planned [2,13] well in advance and the curriculum and schedule must be changed accordingly so that teachers can provide quality education.
- All the necessary support and assistance [12,13] need to be provided to students, teachers, and staff members to overcome the fear of technology. Regular workshops and webinars need to be arranged to provide the necessary knowledge and support.
- Teachers should be prepared and motivated has to opt for effective online teaching methodologies [2, 12, 13] i.e., they need to take care of voice modulation as voice is the only media in online lectures. They need to engage every student.
- An effective evaluation system [12,13] needs to be opted to access the effort of every student efficiently. Online participation should be graded so that every student can be engaged
- An effective feedback system [11] must be opted to measure student satisfaction.
- Synchronous online teaching must be opted so that students can participate and express themselves.
- New methodologies [2] i.e virtual reality, augmented reality, simulations, gaming should be used to create the interest of students.
- Courses need to be published in different languages [6] to broaden their reach.

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# Effective Teaching for Millennial Learner

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**Abstract :** Learning is a holistic process that involves several key components based on two-way interaction and transfer of knowledge between the learner and surroundings. Given the developments in technology and pandemic situation, finding the right mix of traditional and new learning styles is paramount. Traditional teaching and learning process have failed to create the necessary connect among the millennial learners. Therefore, a judicious use of traditional teaching techniques with the relevant technology will make for an effective tool in converting the millennial student into an active learner. Active learning approach is the first step in making learning an organic process. This approach will not only foster exchange of ideas among peers through discussions, case studies and role plays, but also cater to individual learning styles. The outcome of employing such an approach will promote higher order thinking skills, engaging in deep learning, and facilitate better transfer of knowledge. As there is no standard protocol to follow in technical higher education

teaching, this concept paper is the first step in incorporating learner centric teaching that can bring better congruity and consistency in specific higher education fields.

**Keywords :** Active learning; Blended learning; Experiential learning; Information communication technology; Millennial learner

## 1. Introduction

Since the technology boom in late 90s and early 2000s, access to information that was privy to an elite junta has diminished. With the advent of the internet it is possible for any person to acquire proficiency in a chosen field with little to no supervision at a click of a button.

This unrestricted access to knowledge has led to major shifts not only in classroom dynamics, but also in the way a learner is able to acquire proficiency in a given subject. This trend has been recognized and has led to reputed institutions/universities around the world to offer specifically catered online programs and degrees either on their own or through third party websites [1]. In addition, the pandemic situation has also initiated the shift from a traditional classroom environment to an online setting at a rate faster than expected. These changes in the dynamics of teaching and learning have required mainstream educators to adapt to the changing times and tackle problems

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associated with it such as student mentality, approach to subject [2]. Along with the undeniable advantages of online education such as enhanced teaching and learning, Globalization, no geographical limitations among others; there are certain major negative impacts to it such as declining writing skills, increasing plagiarism, and lack of focus [3]. More often than not, majority of the issues arise due to inability of the teacher to fully harness the capabilities of the online teaching platform.

The pandemic situation in India was severe and the future is still uncertain in regards to offline classes. This situation has forced educators and learners to adapt to the online platform [4]. Though the online platform has some advantages to its credit such as freedom to learn from home, ability to use ICT tools like augmented reality, PowerPoint, polls, and pop quizzes which make classroom discourse engaging for the learner, a major factor for concern is the lack of social interaction with the teacher and inability to encourage active classroom participation. Furthermore, students from poor socio-economic backgrounds may find the use of such online tools intimidating and be a major stumbling block for first time users. In addition, the added pressures from peers, family and family economic situations can further create an unsuitable environment for active student participation.

In this paper, we wish to discuss the challenges posed and provide possible alternatives that can be employed in offline/online classroom settings for effective and relatable course delivery. Furthermore, the teaching techniques discussed here can be used as per discretion of the educator either in conjunction or as standalone exercises as part of classroom engagement comprising of students with different learning styles and socio-economic backgrounds.

#### A. Brain based learning

The primary avenues of learning available for a student are: in-class lectures, individual learning, and peer-based learning. The regular discourse during class provides the student with information with regards to its history, structure, basics and application. This is a crucial step in the learning process and paramount attention has to be paid to communication in-class between the teacher and the student. Audio-visual tools used during the lecture only act as complementary aides; but the primary source of knowledge dissemination to the student is through

regular lecture. The next step in the learning process is through individual exploration through assignments and homework; these not only gives the student an opportunity to further their knowledge by referring to other sources, but also reassess their in-class understanding and develop a personalized approach to the subject. The third step is through peer discussion, wherein students can discuss their experience in the subject either in a controlled classroom setting or in an informal conversation. The advantage here is that by sharing knowledge students get the unique opportunity to validate their learning strategies and sources. Also students will be able to pick up the best learning techniques from their peers. Often major emphasis is given to the first two steps: in class and individual learning with the important peer based learning neglected.

The human brain is geared to learn in small chunks, respond well to repetition, and focus on unusual new inputs. It has also been proven that emotions and social interactions are very crucial towards lifelong learning [5]. Scientific research has shown that neuron creation in brain is the primary basis for lifelong learning and memory. By making students active participants in learning the process of creating neurons is amplified. The research by Geoffrey and Renate, major proponents of brain-based learning clearly devised steps that promote lifelong learning and memory. They said [6],

1. Learners must be immersed in complex interactive experiences
2. Alertness of learners' mind is achieved through challenges.
3. A problem must be given with all possible ways to solve in order to promote insight

Based on the above information, we can formulate a strategy that encourages the learner from being a passive spectator in the class to an active stakeholder. The implications of applying strategies discussed in this paper will not only help the educator in active class participation, but also aid in assessing the level of student understanding of the subject.

#### B. The millennial (Gen X, Y, Z & Alpha) student:

As compared to all the previous generations, there is no doubt the millennial students are the most diverse and largest generation to attend higher education [7,

8]. Traditional teaching practices have been found wanting in addressing the millennial's needs. Their personalities, preference to education, thought processes as a whole makes it a challenge to engage them in a regular classroom setting. Common traits exhibited by millennials are lack of professionalism, sense of entitlement, need for recognition, over-reliance on technology, and unrealistic expectations. In addition, a majority of such students expect to be handed either readymade lecture notes or a “know-how” guide for preparing for their exams. A very dominant trait in a millennial student is his/her reluctance to spend time on understanding, doing the tasks and expect success with minimal to no effort.

Based on the Howe and Strauss's research [9], the characteristic traits in a millennial can be categorized as follows

1. Millennials feel they are special [10]
2. Millennials are sheltered
3. Millennials are team oriented
4. Millennials are confident
5. Millennials are pressured
6. Millennials have strong aspiration [11]
7. Millennials are conventional [12]

In addition, Millennials are extremely good with technology, have short attention span, respond well to communication and are ready to accept change. As the focus of higher education teaching is shifting from a teacher to a more student-centric approach. It is important for the educators to exploit the best features in the millennial student in order to deliver effective and relatable content. Furthermore, as more of the teaching is shifting to the digital media due to the pandemic, the content delivered by the teacher can only be effective if the student is also made an active participant in the learning process through a combination of a variety of instructional delivery methods. The first step in doing so is by understanding the needs of the student and tailoring the teaching process accordingly. In this study we have focused on two aspects of the teaching learning process such as blended learning and active learning to foster engagement of students while learning.

### C. Blended Learning

Knowledge combined with information communication technology (ICT) in education has steadily gained popularity owing to its contribution in promoting the necessary soft skills in a student in addition to learning, achievement, and enhancement in lifelong skill [13]. Further it has been noticed that usage of ICT also helps the instructors to share their best practices, which leads to the improvement in the quality of education imparted and efficiency in student engagement [14]. In a traditional classroom setting, the main emphasis is on the teacher and on the medium of instruction (talk, chalk). Students are typically relegated to writing in-class notes and understand the concepts. This unidirectional approach often leads to some of the students copying the contents from the board without as much as giving a second thought. This often leads to distraction and the student has to catch up during the course of the lecture. In teacher centric approach there is very little opportunity for the student to interact about the course lecture with the teacher/peers. One way to address this is by incorporating Flipped classroom techniques, wherein the roles of the teacher and students are fluid and the focus shifts predominantly from the teacher to the learner [15, 16]. The four attributes of “FLIP” are Flexible (Environment), Learning (Culture), Intentional (Content) and Professional (Educator), which play a crucial role in engaging the students better in the class.

The role of a teacher in a flipped classroom setting is much more demanding than in a regular setting. A large part of the class goes towards organizing and facilitating proper discussion between students, care has to be taken to keep the discussion within the context of discussions. According to research by Mazur et.al, an instructor's role is to facilitate and channel a student's critical thinking abilities [17, 18]. Designing hybrid classes comprising of flipped and traditional methods is popularly known as blended learning. In blended learning, educators play a crucial role in its implementation and success as a lecturer and as a facilitator. Educators have to actively influence, guide and make students participate to create a student centric learning environment [19]. Some of the best practices of blended learning are elucidated below.

Digital study materials: Instead of giving handwritten notes or printed materials students are encouraged to use digitized course content. The course contents are prepared by the educators by

compiling the contents from various sources. The educator also provides additional information in addition to the contents of the curriculum. This helps the students in gaining extra information for research and also to further their interest in that particular course. A major advantage of this method is that the reading material can be downloaded and used offline at their convenience. It also provides a green alternative by reducing the consumption of paper.

**Video study material:** Research has shown visualization has a positive influence on a learner's memory retention and understanding of the subject. A recorded video lecture provides slow learning students with an opportunity to revisit the lecture and familiarize themselves with complex sections of the lecture. Further, it also aids students who have missed the lecture to catch up with the rest of the section. These recorded lectures also act as good review guides for students while prepping for assessment tests and exams. Selected YouTube videos can also be considered as supplemental lectures in addition to the regular discourse. Video lectures can also be used as an aid for experiments as part of lab component. It can be helpful for students to prepare for practice sessions and make them think regarding the conduction of the experiment. This in turn would get the students to ask queries related to the experiment prior to the practice session.

**Games:** Games have been an integral part of childhood and appeal to demographic of any age group. The purpose behind incorporating games as part of learning is to boost student engagement and enhance high-level critical thinking. Jeopardylabs.com is one such website that allows instructors to design interesting games for a few topics of the chosen course. The games can be varied in nature for example, in the game answers will be displayed and students will be asked to formulate the question; which is a drastic shift from the traditional way, where the educator asks the question always. It also helps to foster collaborative and communication skills.

**Quiklrn:** Taking the advantage of smartphone usage, an android based app designed exclusively for students and educators. This app developed by Quiklrn Private Limited [20], provides a unique platform wherein, the study material can be customized according to learner's convenience. In addition to many relevant features this app when coupled with Google meet can be used to conduct

proctored online tests/exams, by providing appropriate guidelines to the students.

**Practice session:** Skill enhancement is facilitated through practice. It helps supplement theory learned in class and from textbooks. Theory and practice sessions go hand in hand in developing deep and lifelong learning. During lab sessions experiential learning experiments can be included to increase their creative, confidence and skill in conducting experiments. During these experiential learning-based experiments, students perform the experiments with little to no monitoring and are encouraged to research the experiment on their own.

**Animated study material:** PowerPoint presentations are used as audio-visual aids by the educators to explain the concepts better in class. While listening to the educator's explanation, it's cumbersome for the students to draw/note down the contents displayed in the presentation while keeping pace with the lecture. Moreover, some of the concepts are better understood with animation and visualization. The presentations can be used as tools to refresh student's memory as they read the material at a later point.

**Experiential learning:** Lifelong skill and team experience is very much essential in professional life and it is crucial to nurture this habit in students from a very early stage. By the use of EL techniques, students are made to work as a team to understand the principle, methodology and solve problems. This results in better communication skills, adaptability, understanding to work in multi-disciplinary environment, etc. In addition, students become better at coming up with innovative ideas and applying out of the solutions.

**Exposure to research:** It is crucial for a teacher to properly indoctrinate the relevance of the course in terms of current context. This can be achieved by making the students aware of the current technological advances in the subject. Regular visits to a R & D/Industrial facility either on or off campus is the first step in piquing the interest of the students. The fruitful interaction with domain experts and exposure to the state-of-the-art technology will definitely be a lifelong learning experience. **Online Courses:** Many of the accreditation bodies/ organizations around the world have introduced online courses in their accreditation criteria like MOOC, NPTEL, SWAYAM and COURSERA, etc. Related to their courses

students can avail this opportunity to further their knowledge. This opportunity can also be availed by faculty to improve on their course content and learn newer teaching techniques. The advantage of using this technique is that the necessary academic requirements are fulfilled, and learning happens in a flexible environment with accountability.

#### D. Active Learning

The 21st century society needs individuals who are adaptable, innovative, and proactive to tackle societal challenges. The 'knowing of knowledge' is just not enough to be successful in complex issues, evolution is key. Enhancement of life-long learning and potential success can be achieved by initiating early training of the learners in their respective domains. These skills are an integral part of the NEP 2020 curriculum.

In the learning space, active learning promotes students to transition from being passive to active. Students are constantly engaged in problem solving, question and answer discussion, question formulation discussion/ brainstorming, narration, explanation, during the class. The outcomes of employing active learning techniques are enhanced student participation, improved memory retention, longer attention span, student ownership of their learning, exciting classroom environment, innovative thinking, and reduced lecturing of course material.

In addition, active learning techniques such as concept mapping, minute paper, Think Pair Sharing, real life application-based learning, simulation, modeling and group discussion can also be employed for active student participation. Through these activities students develop a sense of ownership and accountability towards their learning; which in turn enhances their creativity, critical thinking skills and team spirit. Use of activities like polls, activity, jokes, puzzles, etc interspersed with regular lecture can help maintain students focus on the discussion. Prior knowledge of students likes/dislikes and disposition can be used as the foundation to design these activities. Relationship of the course content with existing knowledge can be done through active learning strategies.

According to research the average attention span of a student in class is approximately 15 minutes. This information can be used to design lectures which are fifteen minutes each and allow students to process the

information in the brain actively. Active learning strategies can be for classes of any strength and backgrounds. It can be done either as an individual or a group exercise. A generic list of activities with time limits is given in Table-1 as reference.

**Table 1 : Time requirement for different activities**

| Under 6 min                | 6-10 min                                 | 10-20 min                              |
|----------------------------|------------------------------------------|----------------------------------------|
| Class Polls                | Verbal Quizzes                           | TAPPS (ThinkAloudPair Problem-Solving) |
| Fish Bowl<br>Minute Papers | Problem Solving Exercise                 | Concept Tests                          |
| Think, Pair & Share        | Critical Thinking Exercises<br>Role play | Case Studies                           |
| Designing Questions        | Brainstorming – Reverse Brainstorming    | Concept Map                            |

After the content is delivered the educator must summarize the concept, ask questions related to the concept, its application, student's their opinion. The active learning techniques mentioned in Table-1 are discussed below in detail.

**Polls:** It is the easiest and most effective strategy to get immediate feedback from the students. Various apps/software to conduct them like ppt, pollseverywhere, mentimeter, etc. can be used to conduct polls at any given point during the lecture. There are many case studies available in literature proving the efficacy of polling during lecture. An analysis of a student's metacognitive skill has been [21] using a polling mechanism.

**Think Pair Share:** For a given topic students will turn to their neighbors for discussion and then present their combined ideas to the entire class. This is an effective strategy for students who are inherently shy and face problems communicating in large groups. The significance of think-pair-share (TPS) technique as a measure of state anxiety and social evaluative concern is given in literature [22].

**Minute paper:** Students are allowed to use a small paper to give their feedback in one minute at the end of class. Minute paper has lots of benefits for students and teachers [23]. The originality of minute paper is derived from its multi-layered qualitative approach, which provides a deeper insight into the direct and indirect mechanisms of learning.

**Fish bowl:** This can be done at the beginning or end

of class. In which students will be writing one concept for which they need clarification. The paper can be dropped in a box without a name. The educator then picks up a random paper from the bowl and clarifies the concept. This is very helpful for students, who are hesitant to ask questions or are introvert by nature. This could also be considered as an extension of minute paper activity.

**Brainstorming:** Brainstorming is a simple yet effective technique in which all the learners of the class can participate and contribute. The educator asks open ended questions related to a topic and facilitates healthy discussions/debates to encourage out of the box thinking. During the discussion, students discuss and share their perspective in front of the class which is further put up for iteration among other groups. It is very helpful in solving real world problems.

**Games:** As discussed in previous section games are always fun and boost active participation among students. A big cause of concern the veracity and seriousness of such games in higher education. The need for developing a suitable rationale is highlighted and requires relevant considerations [24].

**Case studies:** Case studies are real-life experiences or problems that help students to make a connection between the theory concept and a persisting real-world situation. Educators can design or collect case studies that can relate to the topics of the curriculum. In literature many examples of case studies are given. One interesting example of a system based on ammonia fuel cells is reported.

**Designing questions:** In this exercise students are required to frame questions and write what the answer is they are expecting for the questions. This subtle role reversal will give the students valuable insight into what is expected while setting a question paper and how to answer the questions. Further, a selection of the questions set by the students can be used as a question bank of sorts for future reference.

**Problem-based Learning (PBL):** In PBL, the primary focus of imparting education is through problem solving and team-based learning. Study on strategy to implement PBL has revealed that it is an ideal evidence-based option to fill the skill gaps to foster critical thinking in generation Z [25].

**Role play:** Role playing is a deliberate acting out of a problem statement in a classroom. This helps

students see reality through the eyes of the society. Students not only get a clear understanding of the theory concepts, but also gives them an insight into the modalities of practical application and its effect on society. The effect of role playing as a tool of preconditioning in students of macroeconomics and informatics is highlighted as a select case study [26].

**Verbal quiz:** The class can be split into many groups of size 3 to 5 members of diverse performance criteria with regular quiz rules. In this way students can learn from each other and inculcate a sense of friendly competitive spirit in them. Students feel they achieved more in learning compared when they did the task alone.

**Concept mapping:** Concept mapping is a systematic methodology that recognizes participants' expertise through their experiences. This approach uniquely blends quantitative and qualitative techniques to create illustrative, structured conceptualizations for a diverse group of students. Concept mapping can be used as an effective tool for research and evaluative strategies. Dare et.al [27] have reported better retention and deep learning in students through concept mapping.

## 2. Conclusion

21<sup>st</sup> century education is evolving with the technology and the onus is on the educator to adapt to the changing times to make course content palatable to the millennial students. Traditional teaching methods are no longer sufficient and require an upgrade in terms of combining them with other teaching techniques. In this paper we discuss the various techniques that can be employed by a teacher in-class to make the course content interesting, relevant and more importantly accessible to the students. Furthermore, these techniques also help the educator to address students of diverse backgrounds equally and transform them from passive listeners to active stakeholders. These techniques also promote critical thinking, deep learning and creativity among students. The need of the hour is that education is the key to developing sources of creativity. Psychologists suggest that creative patterns contain activities to invent, to design, to explore, to integrate and to implement can lead to higher intelligence. By employing active learning strategies and blended learning techniques students learn the content and also process it well, which in later stages makes better students and better professionals. TA

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# Educational aid for dynamic study of DC converter with Leverrier's and Pole clustering technique using simulation software

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**Abstract :** In this paper, the dynamic analysis of the dc-dc converter is proposed with an educational aid to ease the process in which the study is carried out. This study's primary importance is that it can be added to the curriculum of Master's program in Electrical Engineering. This article mainly focuses on the mathematical modelling of the dc-dc converter with which the dynamic analysis is carried out to regulate the load and line condition. The main problems in the analysis of higher-order dc-dc converter is addressed with techniques available in the literature. A quadratic boost converter with DCL cell is chosen for studying the dynamic analysis with the flow of the technique proposed. The solution to the resolvent matrix of the converter is obtained using Leverrier's algorithm. The higher-order system's transfer function is reduced using the pole clustering technique to ease the controller design. Finally, the PI controller is tuned with Ziegler-Nichols tuning and it is incorporated with the converter using the reduced-order transfer function. The input to output transfer function is

analyzed with the step response in MATLAB software and compared with the full order transfer function to validate the reduced-order transfer function. The closed-loop response is also validated both with full order and reduced-order system.

**Keywords :** Bloom's taxonomy, Leverrier's algorithm, Pole clustering, DC-DC converter, dynamic, reduced-order, controller

## 1. Introduction

In 1956, Benjamin Bloom, a psychologist, had recommended Bloom's taxonomy (learning objectives) for educators. It has recently been updated with six levels of learning that can be used to frame the learning objectives for any course. Bloom's taxonomy levels are remembering, understanding, applying, analysing, evaluating, and creating (RUA2EC). It is also observed that Bloom's taxonomy intrudes in the assessment process [1] and in framing the curriculum for bachelor's and master's programs. Many articles are recently published on the correlation of Bloom's taxonomy with many undergraduate courses [2]. Fig 1 reveals the latest levels of Bloom's taxonomy. Mostly, many countries follow this level for upgrading the teaching-learning methodology.

According to Bloom's taxonomy, the sixth level is creating a novel or innovative work on its own. To meet out this learning objective, the study should be

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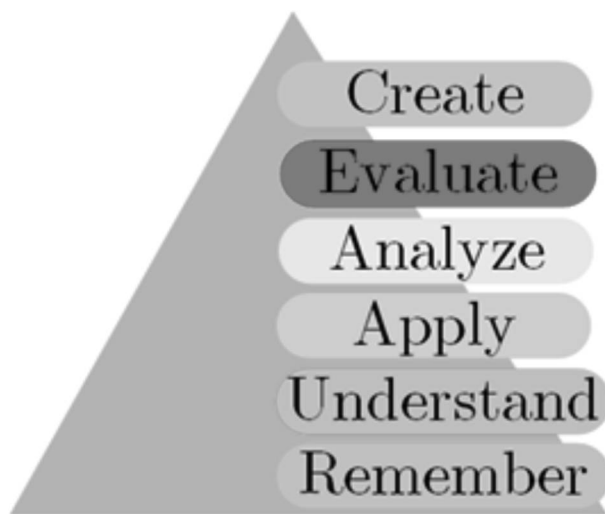


**Fig. 1: Six levels of Bloom's taxonomy**

exposed to design, develop, construct, assemble, and investigate. To develop a model, students should be in a position to create the entire system.

Postgraduate students who are interested in fetching degree on power electronics and industrial drives are needed to learn the courses like

- Analysis of power converters
- Modelling of power converters
- Power electronics converters in a renewable energy system
- Power converters in solid-state DC and AC drives
- Design of controller for power electronic applications.

To ease the mathematical analysis of power converters for all the above courses, this paper has introduced a simple algorithm for performing a dynamic analysis of power converters. The algorithm is explained with a flowchart and an illustrative example for better understanding.

Fig 2 depicts the process involved in the proposed methodology to study the dynamic analysis of the converter. It is a four-step process where four techniques are integrated to analyze the performance of the converter. All these techniques were used earlier for several analyses. However, this is the first time

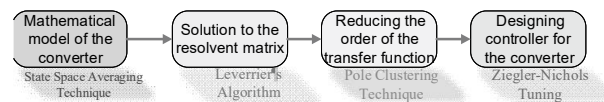


**Fig. 2: Process to carry out dynamic analysis**

these techniques are combined and suggested a methodology to study the dc-dc converter.

To perform dynamic analysis on power converters, many modeling techniques are incorporated [3-10]. In the last four decades, model reduction techniques attracted many researchers to design and model the system. They are several frequency and time-domain model reduction techniques. Frequency-domain techniques such as pole clustering, Pade approximation, Routh approximation, and Routh stability are mostly used to reduce the order of the dc-dc converter's transfer function [11-15]. Pole clustering is observed to be simple in calculating the numerator and denominator of the reduced-order model. Hence, it is chosen and adopted for this methodology. Finally, the controller is designed for the topology to meet the required design needs.

For many industrial applications, the PID controller is deployed. PID controller is employed for a didactic thermal plant in an Arduino platform [16]. In this controller, the tuning parameters are obtained with step response-based Ziegler-Nichol's method. A novel method of tuning is proposed for the PID controller, which unifies the Ziegler-Nichols method [17]. For the magnetic levitation system, the fractional-order PID controller's controller parameters are tuned by the Ziegler-Nichols method and ant colony optimization algorithm [18]. Ziegler-Nichol's method is also used for pneumatic soft robot control systems adjusted manually and automatically [19].

PI controllers are also used for various power converters to implement several control strategies for many applications. The isolated phase-shifted full-bridge dc-dc converter is proposed for a hybrid electric vehicle with particle swarm optimization where the PI controller is tuned with the Ziegler-Nichols method [20]. Ziegler – Nichol's method is also known as the critical proportionality method, which is a widely used heuristic parameter adjusting technique. The precise steps are to detach the differential and integral links, set the scale to a small value, fix the converter in closed-loop operation, and steadily increase the regulator's scale  $K_p$  to attain

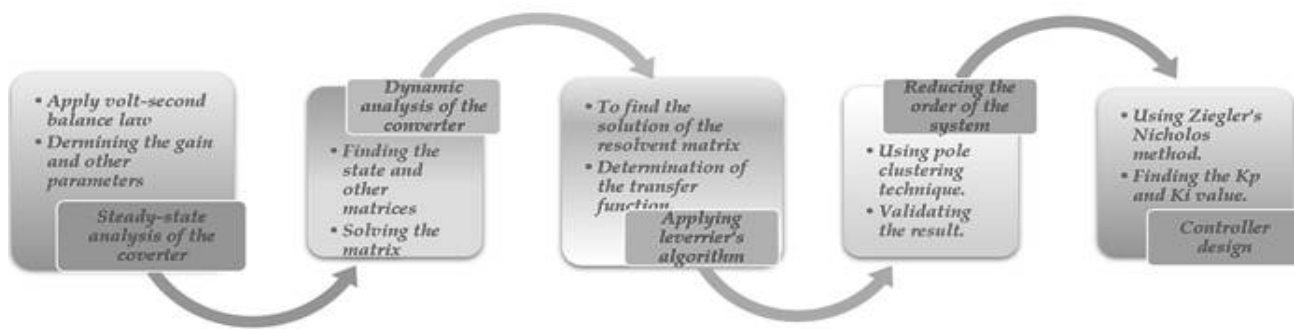


Fig. 3: Step-by-step procedure for this methodology

critical oscillation progression. The gain is called ultimate gain, and the time between two peaks is called critical or ultimate oscillation period. Ziegler – Nichol's method proposes two tuning ways [21], one based on step response and another on frequency response experiment. In this paper, the frequency response method has been followed. This method produces good initial  $K_p$ ,  $K_i$ ,  $K_d$  value. This method remains the most straightforward technique from the tuning point of view.

Fig 3 depicts the step-by-step procedure involved for this pilot study. This paper deals with the mathematical modelling of the power converter (dc-dc converter) and designing a suitable controller for the proposed dc-dc converter. Recent educational tools for the design of power converters are elaborated in section 2. Section 3 describes the mathematical modelling of derived topology. Section 4 describes the simplified method and its application to the topology for solving the resolvent matrix. Bringing down the transfer function's order is to ease the controller's design for a power converter and is discussed in section 5. A suitable controller is suggested for the derived topology in simplified form is presented in section 6. The discussed algorithm is validated with an example in section 7. Section 8 presents the experimental results of the pilot study carried out. Finally, the results are validated in section 9.

## 2. Recent And Modern Educational Tool For Power Electronic Design

Several simulation packages are available for students and researchers for design of novel power electronic converter topologies. These softwares can also be used as a teaching tool for undergraduate and postgraduate students to understand the operating principle of the existing converters in literature. In these packages, few softwares are open-source or the

trail/demo versions are available for the study. In our institution, SRM institute of Science and Technology, there are around six softwares exclusively for power converters. Fig 4 presents the software more commonly used for power electronic converter design and analysis.

Various hardware components for power electronics are also available to enhance the teaching methodology and to increase the interest in the course taught. For example, National Instrument (NI) have lab View, My Rio and compact Rio for the students to learn the concept more clearly by introducing these components along with the conventional method of teaching. Similarly, OPALRT platforms recently an equipment which is used for validation and testing of the power electronics in any real-time application. Students can be exposed to this modern equipment to under the concept in easier way with depth of knowledge.

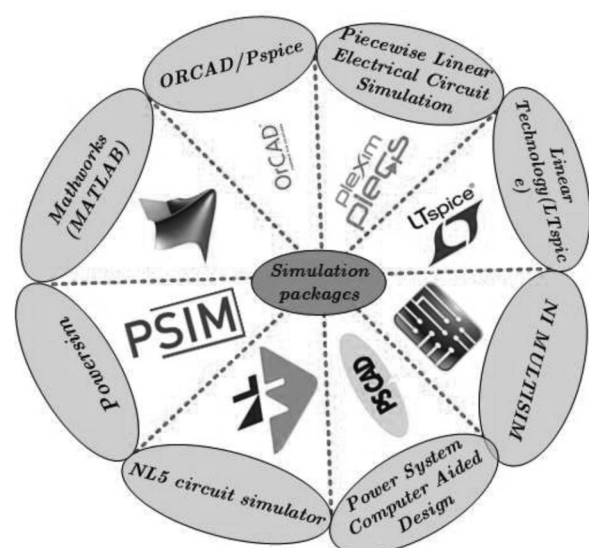


Fig. 4: Simulation packages for power electronic circuits

In addition to this, several controllers like dSPACE, FPGA, DSP are available for designing the controllers for power converters designed and validated. Now a days, all the renewable power source emulators are available along with the power conditioning unit to learn and analyse about the integration of the power converters with grid for distributed generation.

### 3. Mathematical Model Of A Quadratic Boost Converter With Dcl Cell (qbdcl)

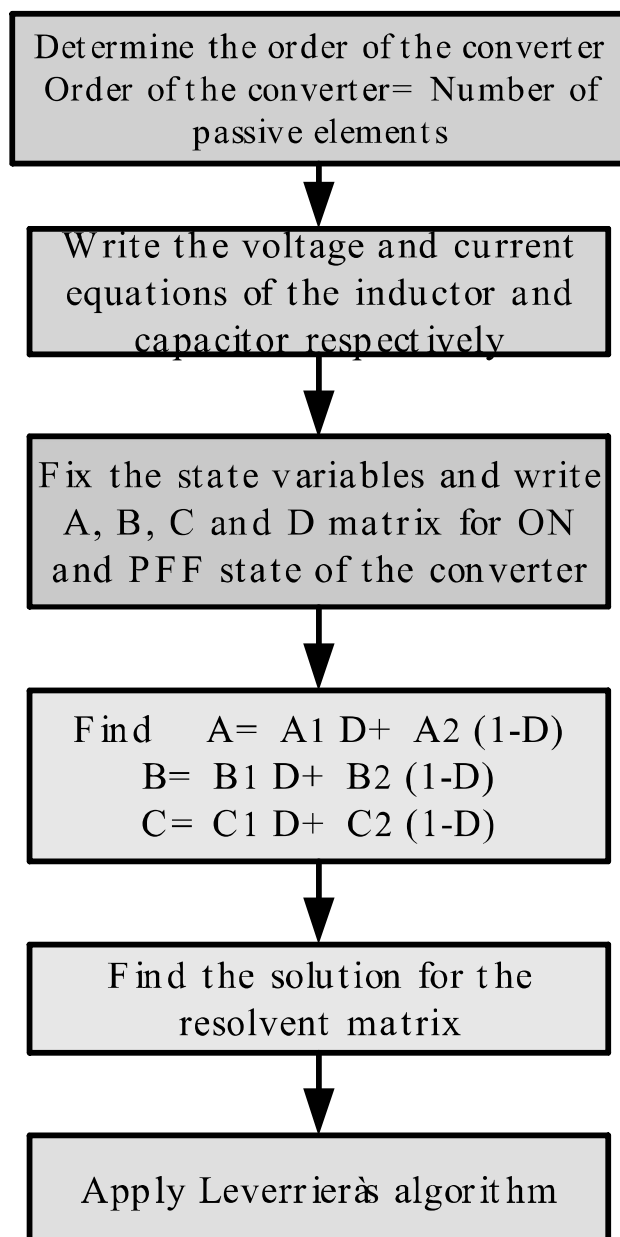


Fig. 5: Mathematical modelling of QBDCL converter using SSA

One of the most popular modelling technique 'SSA' is generally used to obtain a higher-order DC-DC converter transfer function. This is a simple modelling technique purely based on matrix algebra. Resolvent matrix  $(sI-A)^{-1}$  calculation becomes troublesome as the matrix's order increases, making it more prone to error and difficult to arrive at the transfer function. This method uses the scalar Laplace operator 's', making it challenging to calculate through digital computers.

One such algorithm named Leverrier's Algorithm [10] comes very handily to calculate the matrix's inverse. This is a well-known algorithm, and it has been reported in very few articles for computing the inverse of the resolvent matrix  $(sI-A)^{-1}$  of the dc-dc converter during its transfer function determination.

$$X(t) = Ax(t) + Bu(t) \quad (1)$$

$$Y(t) = Cx(t) + Du(t) \quad (2)$$

The state-space equation for QBDCL converter for ON and OFF modes is presented as

$$X_1'(t) = A_1x(t) + B_1u(t) \quad (3)$$

$$X_2'(t) = A_2x(t) + B_2u(t) \quad (4)$$

The output equations at ON and OFF modes are

$$y(t) = C_1x(t) + D_1u(t) ; \quad (5)$$

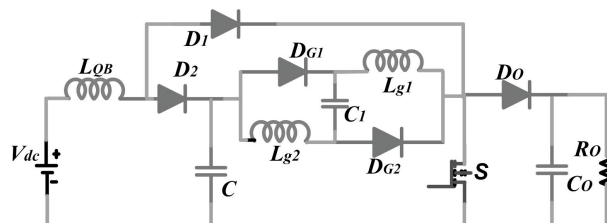


Fig. 6: Quadratic boost with DCL cell (QBDCL) converter

The steps involved in modelling the dc-dc converter is presented in fig 5.

The generalized state-space model of a system is given by

To illustrate the methodology, quadratic boost converter with the diode-capacitor-inductor (DCL) cell which is depicted in Fig 6 is chosen. Since the number of passive components is high, this converter is considered for further analysis. The state, input, and output matrix of shoot and non-shoot through the converter period are obtained and tabulated in table 1.

**Table 1 : State-space Representation of Qbdcl Converter**

| State-space representation of QBDCL converter                                                                                                                |  |                                                               |                                                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---------------------------------------------------------------|------------------------------------------------------------------|
| ON state                                                                                                                                                     |  |                                                               |                                                                  |
| State matrix                                                                                                                                                 |  | Input matrix                                                  | Output and feedforward matrix                                    |
| $A_1 = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1/L_{g1} & 0 \\ 0 & -3/C & 0 & 0 \\ 0 & 0 & 0 & -1/R_0C_0 \end{pmatrix}$                                     |  | $B_1 = \begin{pmatrix} 1/L_{QB} \\ 0 \\ 0 \\ 0 \end{pmatrix}$ | $\begin{matrix} C_1 = (0 & 0 & 0 & 1) \\ D_1 = (0) \end{matrix}$ |
| OFF state                                                                                                                                                    |  |                                                               |                                                                  |
| $A_2 = \begin{pmatrix} 0 & 0 & -1/L_{QB} & 0 \\ 0 & 0 & 1/3L_{g1} & -1/3L_{g1} \\ 1/C & -1/C & 0 & 0 \\ 0 & 1/C_0 & 0 & -1/R_0C_0 \end{pmatrix}$             |  | $B_2 = \begin{pmatrix} 1/L_{QB} \\ 0 \\ 0 \\ 0 \end{pmatrix}$ | $\begin{matrix} C_2 = (0 & 0 & 0 & 1) \\ D_2 = (0) \end{matrix}$ |
| Combining ON and OFF state                                                                                                                                   |  |                                                               |                                                                  |
| $A = \begin{pmatrix} 0 & 0 & -D'/L_{QB} & 0 \\ 0 & 0 & [1+2D]/3L_{g1} & -D'/3L_{g1} \\ D'/C & -[1+2D]/C & 0 & 0 \\ 0 & D'/C_0 & 0 & -1/R_0C_0 \end{pmatrix}$ |  | $B = \begin{pmatrix} 1/L_{QB} \\ 0 \\ 0 \\ 0 \end{pmatrix}$   | $\begin{matrix} C = (0 & 0 & 0 & 1) \\ D = (0) \end{matrix}$     |

In A, B, C and D matrix, substitute  $D+\tilde{d}$  in the place of d and derive the state-space equation with perturbation.

$$\begin{pmatrix} \tilde{I}_{LQB} \\ \tilde{I}_{Lg1} \\ \tilde{V}_C \\ \tilde{V}_{CO} \end{pmatrix} = \begin{pmatrix} 0 & 0 & -D'/L_{QB} & 0 \\ 0 & 0 & [1+2D]/3L_{g1} & -D'/3L_{g1} \\ D'/C & -[1+2D]/C & 0 & 0 \\ 0 & D'/C_0 & 0 & -1/R_0 C_0 \end{pmatrix} \begin{pmatrix} \tilde{I}_{LQB} \\ \tilde{I}_{Lg1} \\ \tilde{V}_C \\ \tilde{V}_{CO} \end{pmatrix} + \begin{pmatrix} V_C/L_{QB} & 1/L_{QB} \\ (2V_C + V_{CO})/3L_{g1} & 0 \\ -(I_{LQB} + 2I_{Lg1})/C & 0 \\ -I_{Lg1}/C_0 & 0 \end{pmatrix} \begin{pmatrix} \tilde{d} \\ \tilde{V}_g \end{pmatrix}$$

#### 4. Flowchart For Leverrier's Algorithm For Dc Converter

Let the matrix A be of order  $n \times n$ , then according to Leverrier's algorithm resolvent matrix is given by

$$(sI - A)^{-1} = \frac{Adj(sI - A)}{[sI - A]} = \frac{P_{n-1}s^{n-1} + P_{n-2}s^{n-2} + \dots + P_1s + P_0}{s^n + b_{n-1}s^{n-1} + b_{n-2}s^{n-2} + \dots + b_1s + b_0} \quad (7)$$

Here,  $P_i$  is a  $n \times n$  matrices and  $b_i$  are scalar

Step 1 : Define  $P_{n-1}$  as  $n^{\text{th}}$  order identity matrix and find coefficient  $b_{n-1}$

Substitute the values of 'b' and 'p' to get final value of resolvent matrix.

$$P_{n-1} = I_n \quad (8)$$

Where  $I_n$  is the  $n^{\text{th}}$  order identity matrix

$$b_{n-1} = -\text{trace}(P_{n-1}A) \quad (9)$$

Step 2 : Calculate next  $P_{n-2}$  and coefficient  $b_{n-2}$

$$P_{n-2} = P_{n-1}A + b_{n-1}I_n \quad (10)$$

$$b_{n-2} = -\frac{1}{2}\text{trace}(P_{n-2}A) \quad (11)$$

For  $j^{\text{th}}$  sequence calculate as  $P_j$  and  $b_j$  as

$$P_{n-j} = P_{n-j+1}A + b_{n-j+1}I_n \quad (12)$$

$$b_{n-j} = -\frac{1}{j}\text{trace}(P_{n-j}A) \quad (13)$$

Step n : Finally calculate  $P_0$  and  $b_0$

$$P_0 = P_1A + b_1I_n \quad (14)$$

$$b_0 = -\frac{1}{n}\text{trace}(P_0A) \quad (15)$$

Input to output transfer function is derived by taking Laplace transform of the output equation which is obtained as

$$y(s) = C[sI - A]^{-1}Bu(s) \quad (16)$$

In equation (16), A, B and C matrix are substituted from the Table I and simplified by the Leverrier's algorithm. The MATLAB coding to obtain the numerator and denominator of the transfer function is given as

```

syms LQB Lg1 D D' C Ro Co S
A= [0 0 -D']/LQB 0;0 0 (1+2D)/(3*Lg1) -D'/(3*Lg1); D'/C -(1+2D)/C 0 0;0 D'/Co 0 (-1/(Ro*Co))];
B= [1/LQB 0 0];
C= [0 0 0 1];
P3=eye (4);
b3=-trace(P3*A);
Q2=(P3*A)+(b3*P3);
b2=-0.5*trace(P2*A);
Q1=(P2*A)+(b2*P3);
b1=-(1/3) *trace(Q1*A);
Po=(P1*A)+(b1*P3);
bo=-(1/4) *trace (Po*A);
Denominator=S^4+(b3*S^3)+(b2*S^2)+(b1*S)+bo
Numerator=B*[(P3*S^3)+(P2*S^2)+(P1*S)+Po] *C

```

Using the above coding, the numerator and denominator of the input to output transfer function is determined as

$$\frac{\widehat{v_O}(s)}{\widehat{v_g}(s)} = \frac{\frac{1+2D}{D'^2}}{\left[1+s\left\{\frac{[1+2D]^2 L_1}{D'^4 R_O} + \frac{3L_{g1}}{D'^2 R_O}\right\} + s^2\left\{\frac{[1+2D]^2 L_{QB} C_O}{D'^4} + \frac{L_{QB} C_1}{D'^2} + \frac{3L_{g1} C_O}{D'^2}\right\} + s^3\left\{\frac{3L_{QB} L_{g1} C}{D'^4 R_O}\right\} + s^4\left\{\frac{3L_{QB} L_{g1} C C_O}{D'^4}\right\}\right]} \quad (17)$$

Further analysis is carried out for the following :

Power= 40 W, Input voltage ( $V_g$ )= 12 V, output voltage ( $V_o$ )= 96 V, Inductor  $L_{QB}$ = 15  $\mu$ H,  $L_{g1}$  =120  $\mu$ H, switching frequency ( $f_{SW}$ )= 60 kHz, Duty cycle ( $D$ ) = 0.5 and load resistance ( $R_o$ ) = 230  $\Omega$ . By substituting these values in equation (17), the input to output transfer function is obtained as

$$\frac{\widehat{v_O}(s)}{\widehat{v_g}(s)} = \frac{18.518 \times 10^{17}}{s^4 + 0.484 \times 10^4 s^3 + 1.239 \times 10^9 s^2 + 0.341 \times 10^{13} s + 2.314 \times 10^{17}} \quad (18)$$

Fig 7 represents the step response obtained from the input to output transfer function of full order converter from Matlab.

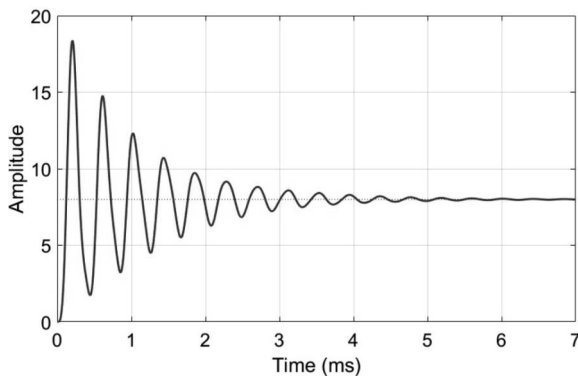


Fig .7: Step response full order QBDCL converter

## I. Flowchart For Pole Clustering Technique For Dc-dc Converter

Mathematical models are carried out to achieve desired performance from a dynamic system. Systems that yields composite models are tough to analyze due to computational cost, or storage constraints. This problem can be solved using model reduction techniques that tends to store the dominant characteristics of the model. This model reduction produces analyzable models whose features like transient response, static response, stability is preserved. This paper follows the improved pole clustering method for reducing the order of the model. Fig 8 depicts the steps involved in applying the pole clustering technique to the dc-dc converter. The model reduction steps involve first calculation of the denominator then numerator.

Let, consider a higher-order system as

$$G_{vFO}(s) = \frac{Num(s)}{Den(s)} = \frac{c_0 + c_1 s + \dots + c_{n-1} s^{n-1}}{f_0 + f_1 s + f_2 s^2 + \dots + f_n s^n} \quad (18)$$

Similarly, the reduced-order model be of the form

$$G_{vRO}(s) = \frac{Num(s)}{Den(s)} = \frac{u_0 + u_1 s + \dots + u_{n-1} s^{n-1}}{v_0 + v_1 s + v_2 s^2 + \dots + v_n s^n} \quad (19)$$

### 5.1 Calculation of denominator:

The rules for Clustering of poles:

- Distinct clusters are segregated for real and complex poles.
- Poles lying in the left and right half of s plane are separately grouped.
- Purely imaginary and zero poles are retained in the approximate system.

Suppose poles are given by the following equation

$$Den(s) = (s + \alpha_1)(s + \alpha_2)(s + \alpha_3) \dots (s + \alpha_r)(s + \alpha_{r+1}) \dots (s + \alpha_{2r})(s + \alpha_{2r+1}) \dots (s + \alpha_n) \quad (20)$$

Assume that the model is needed to follow up 'rth' reduce order, then the number of clusters formed is equal to r. The first pole is placed in first cluster, second in the next cluster, similarly rth pole in rth cluster, again (r+1)th pole in the first cluster, (r+2) in second, (2r) in rth cluster and the process continues until all the poles are set up in clusters. Each pole in a cluster is arranged in ascending order considering only magnitude value.

Setup the model taking the cases given below

Case 1: - All poles are real

The denominator is obtained as

$$Den(s) = (s - \partial_1)(s - \partial_2)(s - \partial_3) \dots (s - \partial_r) \quad (21)$$

Case 2: - All poles are complex

Apply the algorithm for the real and imaginary parts separately. The denominator of the lower-order system is given as

$$Den(s) = (s - \alpha_1 \pm j\beta_1)(s - \alpha_2 \pm j\beta_2) \dots \quad (22)$$

Case 3: Real and Complex pole

An improved clustering algorithm is applied independently for both real and complex terms. For rth order reduced-order system, let  $\gamma$  be the cluster center for real poles, and  $\mu$  be the cluster center for complex poles. Then denominator is given by

$$Den(s) = \prod_{i=1}^{\gamma} (s - \partial_i) \prod_{j=1}^{\mu} (s - \alpha_j \pm j\beta_j) \dots \quad (23)$$

## 5.2 Calculation of numerator:

The numerator of the reduced-order model is

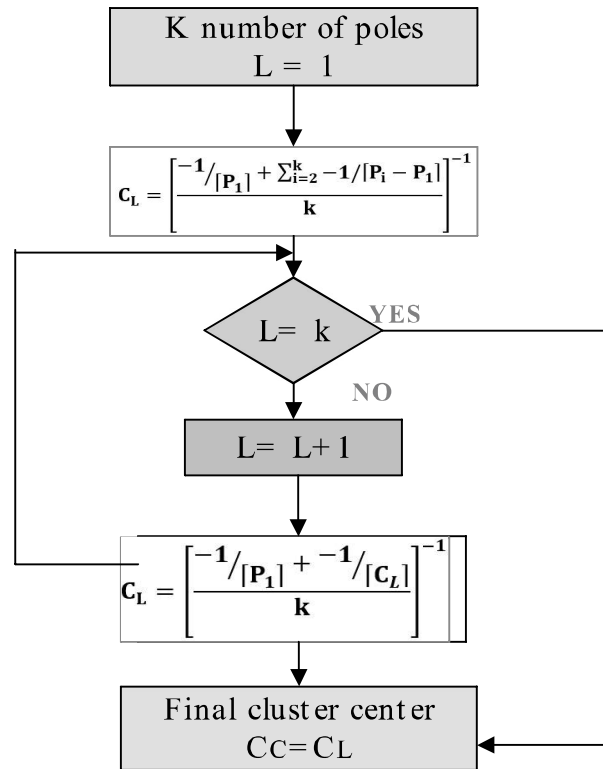


**Fig 8: Steps to proceed with pole clustering technique for DC-DC converter**

calculated using simple mathematical computation [12-14]. It is attained by equating the transfer function of the original order and reduced order converter as stated below

$$= \frac{\frac{g_o + g_1s + g_2s^2 + \dots g_{n-1}s^{n-1} + g_ns^n}{j_o + j_1s + j_2s^2 + \dots j_{m-1}s^{m-1} + j_ms^m}}{q_o + q_1s + q_2s^2 + \dots q_{r-1}s^{r-1} + q_rs^r} \quad (24)$$

'r' number of equations are obtained by equating the powers of S.

$$\left. \begin{aligned} g_or_o &= j_oq_o \\ g_or_1 + g_1r_o &= j_oq_1 + j_qo \\ g_or_2 + g_1r_1 + g_2r_o &= j_oq_2 + j_q1 + j_qo \\ &\vdots \end{aligned} \right\} \quad (25)$$

By rearranging the equations (25), the numerator of the transfer function is obtained. The numerator polynomial coefficients can easily be determined from the known coefficients of the denominator polynomial.

Consider the fourth-order transfer function of the QBDCL converter in equation (18) to reduce to second-order transfer function using the technique

mentioned above. The poles of the full order and reduced order are presented in Table II.

**Table 2 : Poles of the full order and reduced-order qbdcl converter**

| Poles of the full order QBDCL converter                     |  |
|-------------------------------------------------------------|--|
| $\alpha_1 = -1585 + j31647$ ; $\alpha_2 = -1585 - j31647$   |  |
| $\alpha_3 = -839 + j15161$ ; $\alpha_4 = -839 - j15161$     |  |
| Poles of the reduced-order QBDCL converter                  |  |
| $\alpha_1 = -813.6 + j15471$ ; $\alpha_2 = -813.6 - j15471$ |  |

The numerator of the transfer function is calculated by equation (18) with the equation obtained from the poles of the reduced order as per the equation (24). By equating the power of the S, it is acquired as

$$\frac{18.518 \times 10^{17}}{2.314 \times 10^{17}} = \frac{q_o}{240.03 \times 10^6} \quad (26)$$

Solving the equation (26), we obtain the numerator of the reduced-order converter is

$$\text{Num} = 1920.92 \times 10^6 \quad (27)$$

After completing the calculation of numerator and denominator, the derived reduced-order transfer function is

$$\frac{\widehat{v_o}(s)}{\widehat{v_g}(s)} = \frac{1920.92 \times 10^6}{s^2 + 16.2s + 240.03 \times 10^6} \quad (28)$$

Fig 9 represents the step response obtained from the input to output transfer function of reduced-order converter from Matlab.

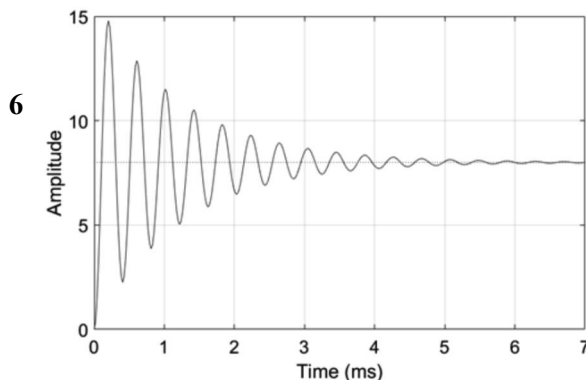


**Fig. 9: Step response reduced order QBDCL converter**

### Flowchart For Controller Design Of Dc-dc Converter

Due to the simplicity in design, the PID controller is the most commonly used control strategy in industries, and its general block diagram is depicted in

Fig 10. The Proportional and integral parameters create a more significant impact on the system's performance, and henceforth, optimal values are essential. The utmost common method of PI tuning is the Ziegler-Nichols tuning method. The simplicity of this method is that its inherent principle in determining the value of  $K_p$  and  $K_I$ . With the system's step response, the  $K_p$  value is set to a small value by keeping the  $K_I$  to zero. The response of the system is observed until it reaches neutral stability [22]. After that, using the formulae given in Table 2, the controller parameter values are obtained. Though, this alike response cannot be obtained for all the systems by fine-tuning the  $K_p$  values.

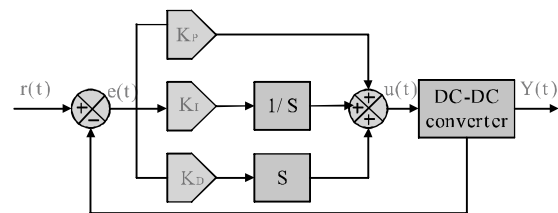


**Fig. 10: General block diagram for DC-DC converter with PID**

$$u(t) = K_p \left( e(t) + \frac{1}{T_i} \int_0^k e(\tau) d\tau + T_d \frac{de(t)}{dt} \right) \quad (29)$$

Simplifying the expression (29), results to

$$u(t) = K_p e(t) + K_I \int_0^k e(\tau) d\tau + K_D \frac{de(t)}{dt} \quad (30)$$

$$\text{Where } K_I = \frac{K_p}{T_i}; K_D = K_p T_d$$

Thus, the final expression of the PID controller is written as

$$G_{PID}(s) = K_p + \frac{K_I}{s} + K_D s \quad (31)$$

Fig 11 illustrates the steps involved in the determination of PID parameters with Ziegler-Nichol's tuning. Table III presents the formula used to calculate the PID parameters with the second method of step response-based Ziegler-Nichol's tuning.

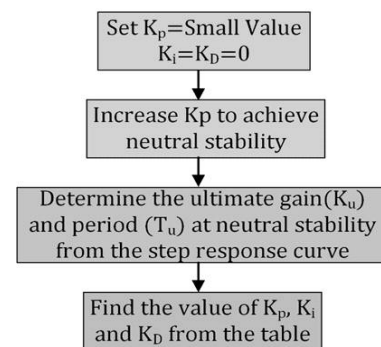


**Fig 11: Steps to proceed with Ziegler-Nichols tuning for DC-DC converter**

**Table 3 : Formula To Tune Controller Parameters in the Pid Controller with Ziegler-nichols Tuning**

| Controller   | Kp     | Ti     | Td   |
|--------------|--------|--------|------|
| PID          | 0.6Ku  | Tu/2   | Tu/8 |
| P            | 0.5Ku  | -      | -    |
| PI           | 0.45Ku | Tu/1.2 | -    |
| PD           | 0.8Ku  | -      | Tu/8 |
| No overshoot | 0.2Ku  | Tu/2   | Tu/3 |

According to Fig 11, the Kp value is set to a smaller value, and the step input response is observed. If the oscillation reaches neutral stability, then the Kp value is set as Ku, and the time period is noted in the sustained oscillation to set as Tu. Finally, the KI is calculated by determining the value of Ti.

**Table 4 : Values Determined By Ziegler-nichols Tuning (step Response)**

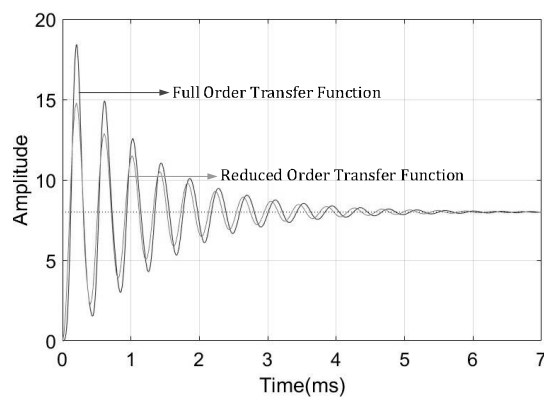
| Ku    | Tu    | Ti      | Kp    | Ki |
|-------|-------|---------|-------|----|
| 0.011 | 0.001 | 8.33e-4 | 0.005 | 6  |

Using the Table IV, the transfer function of PI controller is determined by substituting the values to (31).

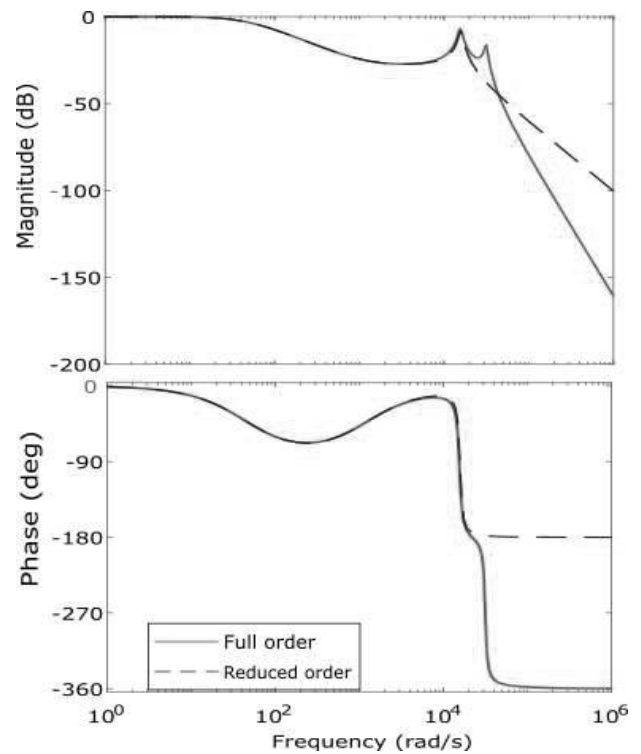
$$G_{PI}(s) = \frac{0.005s + 6}{s} \quad (32)$$

## 7. Validation of the Algorithms

The open-loop response of equations (18) and (28) is determined and presented in Fig 12 (a). From this figure, it is observed that the response obtained from the full order transfer function matches closely with the reduced-order transfer function. To validate the results further, the two transfer functions' bode plot are compared and presented in Fig 12 (b). The bode plot matches closely with a slight deviation.



(a)



(b)

**Fig. 12: Comparison of results (a) Step response of full-order and reduced-order QBDCL converter (b) Bode plot of full-order and reduced-order QBDCL converter**

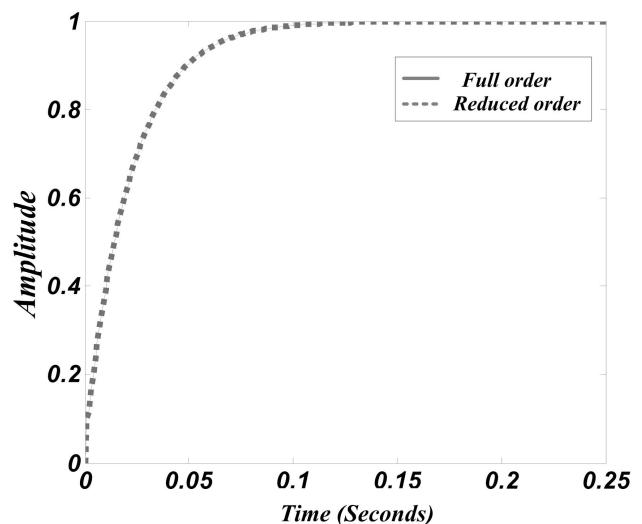


**Fig. 13: Comparison of closed-loop response obtained for full-order and reduced-order QBDCL converter**

**Table 5 :**  
**Comparison Of Time-domain Specification**

| Input to output transfer function                              | Poles                                                                                                                                                       | Zeros | Time-domain specification                                            |
|----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------|
| Full order open loop transfer function                         | $-1585 + j1647$<br>$-1585 - j1647$<br>$-839 + j5161$<br>$-839 - j5161$                                                                                      | Nil   | Overshoot= 130%<br>Rise time= 0.05 msec<br>Settling time= 0.0042 sec |
| Reduced-order-Open-loop transfer function                      | $-813.6 + j5471$<br>$-813.6 - j5471$                                                                                                                        | Nil   | Overshoot= 90%<br>Rise time= 0.07 msec<br>Settling time= 0.004 sec   |
| Closed-loop transfer function with full-order PI controller    | $1.0e+04* 0.0000 + 0.0000i$<br>$1.0e+04* -0.1261 - 3.1677i$<br>$1.0e+04* -0.1261 + 3.1677i$<br>$1.0e+04* -0.0913 + 1.5149i$<br>$1.0e+04* -0.0913 - 1.5149i$ | -1200 | Overshoot= 0%                                                        |
| Closed-loop transfer function with reduced-order PI controller | $1.0e+04* 0.0000 + 0.0000i$<br>$1.0e+04* -0.0814 + 1.5472i$<br>$1.0e+04* -0.0814 - 1.5472i$                                                                 | -1200 |                                                                      |

Finally, (32) is integrated with equations (18) and (28) to receive the closed-loop response of the system. The response received from the closed-loop system of the full order and reduced order is presented in Fig 13. The time-domain parameters obtained from the open-loop and closed-loop response of full-order and reduced-order transfer functions are tabulated in table 5 for comparison. It is noted that the pole clustering technique is best suited to the dynamic analysis of the dc-dc converter, especially for the higher-order transfer function.

This paper has detailed the study carried out in the dynamic analysis of the converter. It introduces the steps involved in analyzing the mathematical model of the converter to design the closed-loop controller. According to Bloom's taxonomy, this methodology can be incorporated in post-graduate curriculum of power electronics courses for improving their design skill. We described the procedure for finding a solution to the resolvent matrix with Leverrier's algorithm. The Matlab coding for the matrix solution is given, which can be used as a teaching tool for finding the transfer function of a newly derived dc-dc converter. Furthermore, the flowchart of the various techniques incorporated is given, which can be used as teaching to explain the converter's mathematical modelling.

An illustrative example is given to explain the proposed methodology. Quadratic boost converter

with DCL cell is chosen for explaining the procedure involved in Leverrier's algorithm, pole clustering technique, and PI Ziegler-Nicholas tuning.

Pole clustering technique is used to reduce the order of the transfer function. The full-order converter's open-loop response is compared with the reduced-order converter to validate the result obtained from the pole clustering technique. It is noted that both the response closely matches the similar value of time-domain parameters. The open-loop response is used to find the PI controller's K<sub>p</sub> and K<sub>i</sub> value with Ziegler-Nicholas step response second method of tuning. The determination of these values is made more accessible to the response obtained from Matlab. Finally, the closed-loop response is determined by combining the PI controller transfer function with the dc-dc converter's transfer function.

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# Design and Validation of the Academic Research Aptitude Scale

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**Abstract :** Universities across the world have now started focusing on creating and nurturing academic researchers. While the importance and benefits of a strong research mindset have been understood, the process of identifying and developing researchers lacks a sense of structure. The current study attempts at filling this gap by proposing and testing the Academic Research Aptitude Scale. The scale was created and tested using the DeVellis (2016) method. The initial pool of items consisted of 29 items that were generated in the course of a brainstorming session. The discussion with experts and literature review resulted in a 22-item instrument which was then reduced to 21 items, post the item analysis. The analysis was carried out on a sample of 303 research scholars and researchers. The exploratory factor analysis helped in the identification of the dimensions and the same was then checked using confirmatory factor analysis. The scale fulfilled the validity requirements and showed high reliability, as shown by

Cronbach's alpha score. The final scale consists of 21 items.

**Keywords:** researchers; research scholars; academics; India

## 1. Introduction

Academic research has been held in high regard for decades. Jaffe (1989) proposed that there exists a correlation between corporate innovativeness, design thinking and proximity to major research universities. Jaffe (1989) cites the example of Silicon Valley and its proximity to Stanford as an example of this spillover effect. This school of thought suggests that to sustain advancement in the corporate world, there must be rigour and focus on developing the academic research potential and research quality.

Researchers must be capable of creating detailed plans for their research work, they must also be flexible to account for any setbacks. They must be task-oriented and still ensure that the work takes into consideration the feelings of the target population. This complexity in the desired aptitude makes the identification and evaluation of a person's research competency extremely difficult. This study attempts to assist in this process by designing and validating an instrument to measure research aptitude, given that competencies can be developed if the inclination and ability exist.

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## 2. Literature Review

As the need for academic researchers rises and universities look at increasing their research talent pool, the process of selection and development of researchers has become crucial. The current study attempts to provide an objective tool for the selection and identification of academic researchers. The tool may also be used as a development instrument to identify the gaps and aid in the development of research scholars.

A search for “research aptitude” did not return any results. Thus, the researchers chose to study the competencies of an academic researcher and use the same to identify an academic research aptitude framework. While there is a consensus that any model for research aptitude must be flexible to take into account the changing requirements of research, some attempts have been made at identifying competency frameworks for research (Research competencies framework, 2007). Showman, Cat, Cook, Holloway, and Wittman (2013) proposed that the traits that would enable an individual to successfully solve a research problem include being organized, good judgment, effective communication, creativity and being persistence. A document published by the Faculty of General Dental Practices, UK suggests that research competencies may be categorised into domains such as practical skills, problem-solving, thinking and communication skills, personal attitudes and professional ethics, dissemination and roles and functions. The dimension of practical skills comprises the ability to find and use resources and facilities like the library and information technology; recognise and identify the use of secondary and primary resources, observe and record behaviours and demonstrate technology usage competency. These skills are associated with the process of conducting research and may be considered basic requirements. While the ability to use information technology and computers is considered essential in this age of technology, the other need for skills of being able to identify and collect information is still relevant. These would be reflected in traits like curiosity, analytical ability and task orientation, which are related to how a researcher approaches and carries out the research. Thus, these traits are likely to reflect the individual's research aptitude.

Curiosity has always been associated with any task that involves inquisitive thinking (Berlyne, 1954). According to Zuss (2012), an individual derives the

desire to learn and acquire knowledge and skills from the quality of curiosity. Thus, in addition to being considered as a quality, curiosity is also regarded as a behaviour that enables constant learning and seeking of knowledge.

Analytical ability refers to the ability to collect the right information, analyse the information and make appropriate decisions or solve problems (Doyle, 2019). This covers the first dimension as well as some aspects of the dimension of thinking and problem-solving. While the ability to find and use various sources is crucial, the advances in technology have made the task simple for those who are motivated to do so. The key requirement is to identify the appropriate or right information. Analytical ability becomes especially critical in this era of information overload.

While the construct of task orientation has been primarily studied in relationship to leadership styles, Ebert, Griffin and Stark (2011) suggest that an individual who is considered task-oriented would ensure the creation of structures and plans to achieve the goals that have been set out. While it may not be considered a desirable leadership style (Bass, 1990), as a researcher it would ensure that research activities are planned and completed in a timely manner and oriented towards the final goal.

The personality traits that a researcher is expected to possess are similar to the concepts explained by Goleman (1998), in their study of emotional intelligence. Achievement orientation would allow the researcher to progress in their chosen field. Achievement orientation provides the individual with the ability to comprehend and react to the situations and tasks accordingly (Dweck & Leggett, 1988). Goleman, Boyatzis, Davidson & Druskat, (2017) explain achievement orientation as part of the Emotional Intelligence competencies. They suggest that achievement orientation allows an individual to "meet or exceed a standard of excellence, welcoming feedback, and continually seeking to improve." The given definition brings into focus the need to aim for excellence and quality work, suggesting that the individual must be willing to go the extra mile to create quality work. The second part of the definition calls for openness towards feedback. The last part of the definition suggests that the individual must be inclined to constant learning and growth by continuously being open to ideas and information that may emerge. The qualities have been studied in the

context of leadership skills but the researchers find that the same would hold for academic researchers too.

While substantial research has been done to develop and understand the various competencies, there is no tool to measure the aptitude for academic research. In the current study, the researchers attempt to fill this gap by attempting to develop one such tool. The understanding of the basic competencies, reviewed in this section, guide the process of identifying the personality traits that would indicate an aptitude for academic research.

### 3. Method

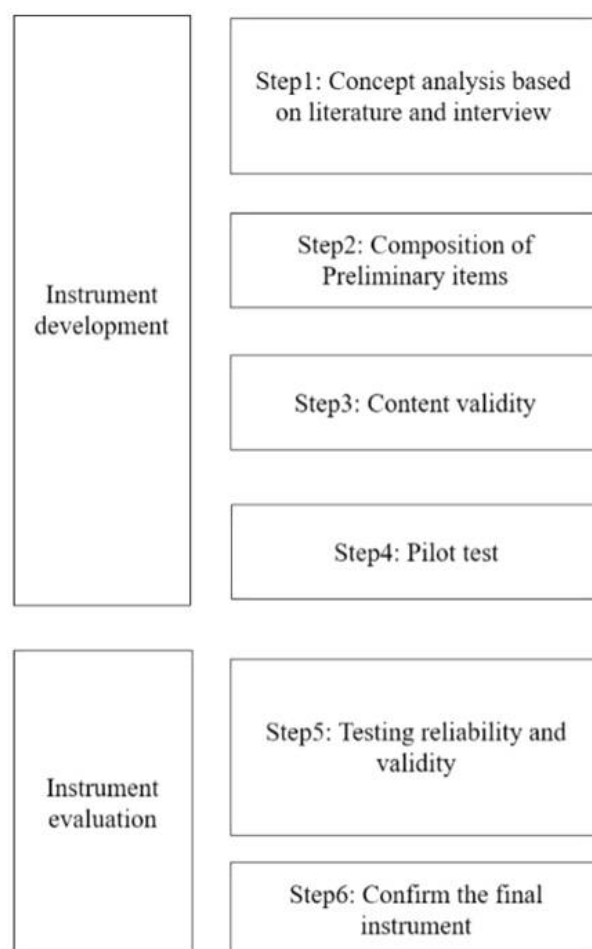
The study uses the DeVellis (2016) method for scale development. The steps of the process have been shown in Figure 1. The first step involves defining the construct. Since the construct is new and the researchers were not able to find a definition for the construct of Research Aptitude, an operational definition was arrived at through discussions with experts and a review of the literature.

The second step was the creation of an item pool. This was done through a brainstorming session. The initial pool was then refined based on inputs from experts. This was the step of content validity. Post the content validity step, the items were refined and a Likert scale was chosen, given the ease of administering and the advice of the experts.

The initial pilot test was carried out to ensure that there were no major issues in terms of difficulty in understanding the statements and the distribution of the responses. Post the pilot study, the instrument was made available to a large sample of researchers and research scholars. The data was then analysed for reliability and validity. In addition, exploratory factor analysis was used to reveal the loading of the indicators onto the respective dimensions or sub-constructs. The dimensions were then labelled based on the review of the literature

The final sample comprised of 303 respondents. This fulfilled the sample requirements for exploratory factor analysis and confirmatory factor analysis. As per Kline (2011), a minimum sample requirement of 200 is required for confirmatory factor analysis. Thus, the researchers aimed to get a sample size greater than 200. However, since the final sample comprised of 303 respondents, the exploratory factor analysis and

confirmatory factor analysis was carried out on the same dataset (Shyamamala, Oh, Cho & Im, 2021).



Source: Shyamamala, Oh, Cho & Im (2021)

Results **Fig. 1: Scale development process**

The analysis of the data was carried out to check the reliability and validity of the scale. In addition, the researchers also used an exploratory factor analysis to identify the dimensions of the scale. The dimensions were then confirmed using a confirmatory factor analysis.

- Concept Analysis

The first step of the process involved the review of related literature. The review of literature helped the researchers arrive at a definition for the concept. Research aptitude may be defined as an individual's natural ability and interest to participate in research activities. Having defined the concept, the researchers focused on identifying the possible dimensions of the scale.

Drawing from a model provided by the Faculty of General Dental Practices, UK, the researchers identified four probable dimensions of Achievement Orientation (AO), Task Orientation (TO), Curiosity (C) and Analytical Ability (AAb). The researchers then proceeded to create a pool of items for the scale. Through the process of brainstorming, the researchers arrived at a pool of 29 items.

- Content Validity

Content validity of the scale was established by a panel of 9 experts. Four experts were chosen from the field of research, four experts included those who were currently involved in the process of selecting and training research scholars. One language expert was chosen to ensure that the statements were correctly worded. The statements were then modified based on the feedback of the experts. Those statements that were labelled as not essential were discussed and post discussion, if the statements were still found to be not relevant, they were dropped from the instrument. Twenty-two statements were retained after this step.

- Characteristics of the participants

The final sample comprised of 303 respondents. The sample consisted of researchers and research students or research scholars, who were currently enrolled in the doctoral program of a recognized university. Table 1 provides the distribution of the sample based on gender and designation.

**Table 1: Distribution of the sample**

| Category           | %    | n   |
|--------------------|------|-----|
| <b>Gender</b>      |      |     |
| Male               | 28.5 | 71  |
| Female             | 40.6 | 101 |
| Prefer not to say  | 30.9 | 77  |
| <b>Designation</b> |      |     |
| Researcher         | 14.8 | 36  |
| Research Scholar   | 85.2 | 207 |

- Item Analysis

This step involved the analysis of each statement or indicator. All items were found to have a skewness

and kurtosis value within the acceptable range of +3 and -3 (Kline, 2005). This would suggest that the data could be considered normally distributed. Each item was then analysed to check for correlation with the overall score. The total score for the Academic Research Aptitude Scale has been represented by the term ARAS and the individual scores were represented by the statement number, for example, ARAS1, ARAS2 etc. All the individual items were found to be significantly correlated to the overall score of the individual, except for ARAS8. Thus, ARAS8 or the eighth statement was dropped from the instrument. Thus, at end of this step, the total number of items was 21. The correlations have been presented in Table 2.

**Table 2: Item and total score correlation**

| Indicator | ARAS                                               | Indicator | ARAS                                               |
|-----------|----------------------------------------------------|-----------|----------------------------------------------------|
| ARAS1     | Pearson Correlation .441**<br>Sig. (2-tailed) .000 | ARAS12    | Pearson Correlation .460**<br>Sig. (2-tailed) .000 |
| ARAS2     | Pearson Correlation .433**<br>Sig. (2-tailed) .000 | ARAS13    | Pearson Correlation .350**<br>Sig. (2-tailed) .000 |
| ARAS3     | Pearson Correlation .436**<br>Sig. (2-tailed) .000 | ARAS14    | Pearson Correlation .428**<br>Sig. (2-tailed) .000 |
| ARAS4     | Pearson Correlation .423**<br>Sig. (2-tailed) .000 | ARAS15    | Pearson Correlation .326**<br>Sig. (2-tailed) .000 |
| ARAS5     | Pearson Correlation .493**<br>Sig. (2-tailed) .000 | ARAS16    | Pearson Correlation .383**<br>Sig. (2-tailed) .000 |
| ARAS6     | Pearson Correlation .384**<br>Sig. (2-tailed) .000 | ARAS17    | Pearson Correlation .324**<br>Sig. (2-tailed) .000 |
| ARAS7     | Pearson Correlation .444**<br>Sig. (2-tailed) .000 | ARAS18    | Pearson Correlation .468**<br>Sig. (2-tailed) .000 |
| ARAS8     | Pearson Correlation .086<br>Sig. (2-tailed) .137   | ARAS19    | Pearson Correlation .195**<br>Sig. (2-tailed) .001 |
| ARAS9     | Pearson Correlation .323**<br>Sig. (2-tailed) .000 | ARAS20    | Pearson Correlation .303**<br>Sig. (2-tailed) .000 |
| ARAS10    | Pearson Correlation .398**<br>Sig. (2-tailed) .000 | ARAS21    | Pearson Correlation .351**<br>Sig. (2-tailed) .000 |
| ARAS11    | Pearson Correlation .385**<br>Sig. (2-tailed) .000 | ARAS22    | Pearson Correlation .479**<br>Sig. (2-tailed) .000 |

- Exploratory Factor Analysis

The next step involved was running an exploratory factor analysis to identify the dimensions. The results of the analysis have been presented in Table 3, Table 4. The Kaiser-Meyer-Olkin Measure of Sampling

**Table 4: Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test**

|                                                  |                                                    |
|--------------------------------------------------|----------------------------------------------------|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | .868                                               |
| Bartlett's Test of Sphericity                    | Approx. Chi-Square 1402.330<br>df 210<br>Sig. .000 |

Adequacy score suggests that the sample was adequate for the analysis. The significance of Bartlett's Test of Sphericity suggests that there exists at least one strong correlation among the items.

**Table 4: Rotated Component Matrix**

|        | Component |       |       |       |
|--------|-----------|-------|-------|-------|
|        | 1         | 2     | 3     | 4     |
| ARAS7  | 0.506     |       |       |       |
| ARAS9  | 0.475     |       |       |       |
| ARAS12 | 0.403     |       |       |       |
| ARAS14 | 0.619     |       |       |       |
| ARAS15 | 0.661     |       |       |       |
| ARAS16 | 0.589     |       |       |       |
| ARAS18 | 0.597     |       |       |       |
| ARAS19 | 0.495     |       |       |       |
| ARAS22 | 0.408     |       |       |       |
| ARAS2  |           | 0.415 |       |       |
| ARAS3  |           | 0.447 |       |       |
| ARAS4  |           | 0.622 |       |       |
| ARAS11 |           | 0.714 |       |       |
| ARAS6  |           |       | 0.549 |       |
| ARAS10 |           |       | 0.459 |       |
| ARAS13 |           |       | 0.521 |       |
| ARAS20 |           |       | 0.483 |       |
| ARAS21 |           |       | 0.718 |       |
| ARAS1  |           |       |       | 0.654 |
| ARAS5  |           |       |       | 0.526 |
| ARAS17 |           |       |       | 0.668 |

The results of the exploratory factor analysis revealed that the data was sufficient. The exploratory factor analysis was conducted using the principal component method using varimax orthogonal rotation. The first factor comprised of 9 indicators, the second factor comprised of four factors, the third factor comprised of 5 indicators and the fourth factor comprised of 3 indicators. The rotated component matrix mapped the statements to four proposed dimensions. The statements under each dimension were further analysed to identify and label the dimension. The

**Table 5: Dimensions of the Academic Research Aptitude Scale (ARAS)**

| Dimension               | Items                                                   |
|-------------------------|---------------------------------------------------------|
| Achievement Orientation | I am open to new information                            |
|                         | I believe in having flexibility in my plans             |
|                         | I am comfortable receiving feedback                     |
|                         | Sometimes listening is more important than speaking     |
|                         | I take care to consider others' feelings                |
|                         | I believe in giving credit when deserved                |
|                         | I believe in going the extra mile                       |
| Curiosity               | I work better when I am given guidelines                |
|                         | I am excited at the prospect of sharing my knowledge    |
|                         | I don't accept information without justification        |
|                         | I am comfortable with raising questions                 |
|                         | I find it easy to put my ideas on paper                 |
| Task Orientation        | When I learn something new, I am keen to find out more. |
|                         | I am comfortable asking for help                        |
|                         | I always get tasks done on time                         |
|                         | I don't allow my biases to cloud my judgement           |
| Analytical Ability      | I believe in setting my own timelines                   |
|                         | I do not allow setbacks to bother me                    |
|                         | I enjoy tasks that require in-depth analysis            |
|                         | I enjoy finding patterns                                |
|                         | I enjoy working with numbers                            |

dimensions along with the statements have been presented in Table 5.

- Confirmatory Factor Analysis

Confirmatory factor analysis was carried out to assess the latent construct. confirmatory factor analysis was also used to the goodness-of-fit, convergent validity and discriminant validity. The fit indices of the model have been presented in Table 6.

**Table 6: Model fit indices**

|                | ( $\chi^2/df$ ) | GFI    | AGFI   | RMR   | RMSEA |
|----------------|-----------------|--------|--------|-------|-------|
| Model Value    | 1.799           | 0.908  | 0.884  | 0.044 | 0.050 |
| Accepted Value | < 3             | > 0.90 | > 0.80 | <0.05 | <0.10 |

The model fit indices reveal that the model is a good fit. All the goodness-of-fit indices were found to meet the required criteria and the RMR and RMSEA values were found to be below the threshold limit. The validity scores have been presented in Table 7.

Convergent validity was assessed from the CR

**Table 7: Measures of validity**

|     | CR   | AVE   | Fornell-Larcker Criterion |       |       |       |
|-----|------|-------|---------------------------|-------|-------|-------|
|     |      |       | AO                        | C     | TO    | AAb   |
| AO  | 0.85 | 0.454 | 0.674                     |       |       |       |
| C   | 0.81 | 0.514 | 0.692                     | 0.717 |       |       |
| TO  | 0.80 | 0.501 | 0.507                     | 0.546 | 0.708 |       |
| AAb | 0.81 | 0.589 | 0.606                     | 0.609 | 0.299 | 0.767 |

or Composite Reliability scores and the AVE or the average variance extracted score. The CR score of all the dimensions was found to be above the acceptable value of 0.7 (Brown, 2015). The AVE scores of Curiosity (C), Task Orientation (TO) and Analytical Ability (AAb) were found to be above the threshold value of 0.5 (Brown, 2015). The AVE score of Achievement Orientation was found to be 0.45. However, according to Fornell and Larcker (1981), if the AVE of the variable is slightly less than 0.5 but the CR score is greater than 0.7, the convergent validity may be considered adequate.

- Reliability Testing

The last step involved analysis of reliability. The Cronbach's alpha value for the overall scale indicated that the Academic Research Aptitude Scale or ARAS had high reliability ( $=0.85$ ). Table 8 presents the results of the reliability analysis of the overall scale with 21 items.

**Table 8: Reliability analysis**

| Cronbach's Alpha | N of Items |
|------------------|------------|
| .846             | 21         |

## Discussion

The growth in academic research is evident from the fact that more and more students are choosing careers in research. The growth of research is critical for the creation of knowledge; a primary expectation from any academic institution. However, research is one such area, where quality, most definitely, trumps quantity. There is a need for more relevant and genuine research rather than sheer numbers. This is also the case when it comes to selecting research scholars. A large number of resources are spent in grooming a researcher and the resources must be utilised in the correct manner. Ironically, researchers have not yet identified a tool to identify and evaluate research aptitude.

The objective of the current study was to arrive at a basic instrument to evaluate the research aptitude of an individual. The researchers chose

to follow the DeVellis method for scale development DeVellis (2016). Based on the review of literature and discussions with experts, the researchers of the current study identified a pool of items that would help in measuring research aptitude. These items were then validated by a language expert and eight area experts. The experts were chosen based on their experience in training researchers and their experience in the field of academic research. Following the advice of the experts, the number of items was reduced and the language expert guided the phrasing of the statements.

The initial instrument comprised of 22 items. The item analysis revealed that one statement was not significantly correlated to the total score. Thus, the item was removed and the instrument contained 21 items. The instrument showed strong reliability with a Cronbach alpha score of 0.846. The Exploratory Factor Analysis revealed that the statements loaded on to the relevant dimensions. The dimensions were identified as Achievement Orientation, Task Orientation, Curiosity and Analytical Ability. The identification of the dimensions was done by analysing the statements that were included in each dimension and matching the statements to known competencies in literature. The dimensions have been shown in Figure 2.

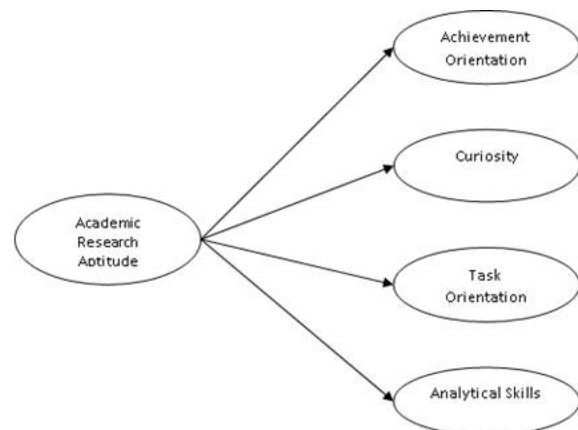


**Fig.2: Dimensions of Academic Research Aptitude Scale**

The first dimension was achievement orientation. This dimension contained statements that reflected the individual's attitude towards

feedback, belief with regards to completion and creation of quality work, openness to information, ethical and empathetic behaviour. The statements cover the dimensions of personal attitudes and professional ethics, roles and dissemination. The statements were found to fit the definition of achievement orientation as given by Goleman, Boyatzis, Davidson & Druskat, (2017). The definition stressed the need to aim for excellence, seek feedback and aim for continuous learning. This is reflected in items such as “I am open to new information”, “I am comfortable receiving feedback” and “I believe in going the extra mile”. Additionally, Dweck and Leggett, (1988) believed that it is also related to the ability of an individual to understand and react to situations appropriately. This is also reflected in the inclusion of achievement orientation as a dimension of emotional intelligence. The items of the scale “I believe in having flexibility in my plans”, “I believe in giving credit when deserved”, “I take care to consider others' feelings” and “I am excited at the prospect of sharing my knowledge” would reflect the individual's ability to comprehend and react to tasks and situations.

The second dimension is that of curiosity. The term may reflect the emotion or behaviour of being curious with regards to the desire to gain knowledge or learn. Zuss (2012) stressed the need for curiosity to drive any development or learning-related behaviour. The statements of the dimension include “When I learn something new, I am keen to find out more”, reflecting a thirst for knowledge. Additionally, statements such as “I am comfortable with raising questions” and “I don't accept information without justification” would suggest the presence of the scientific mindset, which is expected to support learning and the search for knowledge (Montessori, 2013). In addition, the statements also suggest a level of comfort with asking questions and not accepting anything without a proper source or citation; a skill especially critical for those looking to build and create knowledge.

The third dimension in the scale was task

orientation. Statements in this dimension included “I always get tasks done on time”, “I don't allow my biases to cloud my judgement”, “I believe in setting my own timelines” and “I do not allow setbacks to bother me”. These are meant to measure the individual's level of focus on the task at hand. The definition of task management suggests that task orientation would ensure the creation of plans and structures aimed at the completion of tasks (Ebert, Griffin and Stark, 2011). Task orientation becomes significant in research, as the researcher attempts to keep aside personal judgements and setbacks to adhere to timelines. This would ensure the timely completion of projects and derivation of findings and solutions to current problems. The timeliness of the research is the key to determining the validity and value of the findings. Additionally, the ability to persevere even in the face of setbacks would allow a researcher to face obstacles in the course of the project and prevent feelings of dejection on encountering dead ends.

The last dimension in the scale measures the analytical ability of the researcher. According to Doyle (2019) analytical skills is the ability to collect, analyse and interpret information. These capabilities are reflected in the statements “I enjoy tasks that require in-depth analysis”, “I enjoy finding patterns” and “I enjoy working with numbers”. As discussed earlier, the pervasive adoption of technology has made information easily available, researchers must be able to understand and identify information that is relevant, reliable and appropriate. While the dimension has been termed as analytical ability, the statements measure the researchers' attitude towards analytical tasks. The terming has been done to allow for ease of usage and must not be mistaken with analytical skills such as conducting statistical analysis, which would fall into the category of research skills that can be trained (Rumman, 2019).

The identified dimensions are related to inherent or natural skills. This is a reflection of the proposed definition of research competency, i.e., an individual's ability and interest to participate in

research activities. While the current version shows high reliability, the scale would require constant review and modifications to remain relevant. Just as the field of academic research is constantly changing, the scale would also have to be constantly reviewed and modified based on context, sample and usage. The current version provides a starting point on which to build on.

As the researchers set out on the task of creating the scale, the dearth of research articles on researcher aptitude became apparent. The researchers then had to review websites that explained researcher skills and competencies and relate them to key constructs in Psychology. As the number of researchers continues to rise and more and more applications are received for research-based programs, the current scale is intended to help organizations identify the right individuals. This would allow for more efficient use of resources and the selection of worthwhile candidates who would contribute to the advancement of their respective fields through honest and genuine research in the area.

## Conclusion

The objective of the current study was to design a scale that would measure an individual's aptitude for research. This would then enable faster and more accurate identification of persons more suitable for research work and also assist in the identification of areas of development and planning of developmental activities. The items for the scale were arrived at through brainstorming sessions and were validated through a review of the literature and expert opinions. The final list of 21 items was found to represent four major dimensions which the researchers related to achievement orientation, analytical ability, curiosity and task orientation. This identification was achieved through a systematic review of the literature. Although the scale was found to have high reliability and validity, the researchers believe that continuous review and updating of the scale is essential for ensuring the relevance of the scale.

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# Game theory for best results in academics

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**Abstract:** Game Theory (GT) is a technique or tool for analyzing the problems for studying and evolving the strategies, for reaching out towards the rational decision processes of individual persons and their interactions in an environment of a group. Game Theory focuses on studying the different approaches, in which strategic interactions among different economic agents evolve outcomes with respect to the choices (or utility) of the agents, irrespective of whether the results of their efforts were intended. Thus, mostly GT is used for a study of different mathematical models of variations, uncertainties, conflicts and interactions among intelligent; rationally deciding subjects i.e. human beings.

In teaching learning process large number of students, faculties are involved. This results in large number of variables. Large number of students with

unpredictable behaviors, number of faculties with different methods of teaching, makes it difficult to achieve the best academic results. So a study is undertaken and a game theory (GT) is adapted to evolve an academic system so that academic process becomes interesting for the participants that are the students and faculty.

The basic reason of choosing a GT is as it allows users to consider the different variations in the chosen model. The objective of this study is to evolve a composite optimum strategy for the faculty member in-order to achieve the best possible result for any fragmented group of students. The analysis is carried out at the level of some subject in which maximum use of mathematics is observed, such as economics and financial analysis and management.

**Key words:** game theory, strategy, risk, career, decision, higher education, fusion, check and balance

## 1. Introduction:

Game Theory (GT) is best suitable for the study and analysis of strategic and scientific decisions in complicated cases where large numbers of unpredictable variables such as many human beings are involved[01]. According to Ross[02], Game Theory focuses on the analysis of different ways with which various choices or preferences of the variables.

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Using Game Theory study of the strategic interaction among possible economic variables may be performed, irrespective of outcomes and the effects of the persons involved[03]. Therefore in the discussion about the Game Theory, according to Myerson[04] generally it is said that GT is a study of mathematical models of different variables and collaboration between intelligent rationally deciding subjects. Game Theory avails a base for developing mathematical models for analyzing any situations where large numbers of variables are involved. Myerson[04] studied the interaction of individuals and the surroundings where one persons suspected action is modified due to the rational response of another individual or environment. G. D'Agostini[05] explored the possibilities of using Game Theory in academics.

Armstrong[06] showed that, using Game Theory, it is possible to predict the responses of individuals or the system for obtaining the solution within the rational algorithm. For achieving the predefined targets or goals Game Theory helps in deciding the strategy for real or virtual systems. Game Theory can be used where ever the results or behavior is not an outcome of predefined action as GT is much descriptive and normative. Thus Game Theory is used for finding best option where number of variables is involved, or where little complex is involved such as social, ethical or economical behavior.

As the educational processes are much complicated due to unknown variables such as psychological and pedagogical responses of the humans involved, thus for implementing mathematical models basic research of fundamental facts is necessary[07]. According to study presented by Ereneli[08], the results of same teaching methods for different students will be always different; therefore, many immaterial training cannot be quantitatively defined.

Using the Game Theory of generalized Nash games the state conjecture formulation of DTDGs was introduced by Abraham and Kulkarni[09]. Kulkarni and Abraham[10] also presented an approach based on generalized Nash Games and Shared Constraints for Discrete Time which transforms a DTDG into an equivalent generalized Nash game. This research study aims for using Game Theory, for predicting the responses of individuals i.e. students or the system for obtaining the solution within the rational algorithm.

## 2. Use of Games Theory in didactical process planning

Without doing the basic research on psychological and pedagogical responses of individual the perfect mathematical model in actual process of didactical practice is not possible. The outcome of teaching and training process varies from person to person. It depends mainly on students' ability and specifically on memory. A student with good memory will acquire the knowledge better and faster than the one who has poor memory. In the statistical analysis presented by Grațîela and Carmen[11] it is observed that the acquisition of knowledge depends 25 % on memory and 56% on the number of repetition of exercises. From this it may be concluded that the exercises need to be repeated numerous times till the students with poor memory will start remembering it. Although there are chances that due to repetition some students may lose the interest in memorizing the exercise and ultimate result may be poor. One alternative for memorizing the exercise is repetition, but the repetition needs to be optimized to have the best result. In order to get the desired result this optimum number of repetition must be considered. Excess number of repetition may lead to over learning and saturation while lesser number of repetitions will lead to under learning. From the perspective of Game Theory this is a conflicting situation which an academician has to resolve. He has to evolve such strategy so that all students undergoing the exercise should perform with their best possible abilities. This is a game situation between two sides, one is academician and another is students. In this game situation pedagogical results will vary with academician's abilities to choose right method to impart the knowledge and students' abilities to acquire and memorize the knowledge. For example, the academician uses purely Method- 01 e.g. only repeatedly reading the exercise loudly. In another trial, academician uses purely Method- 02 e.g. only repeatedly writing the exercise. The set of 10 problems of moderate level of difficulty were chosen regardless the memory level of students. The performance of student depends on the category in which that student belongs. For uniformity students with 60 to 70 % academic performance were chosen.

The experiment and analysis conducted over 100 students showed that the first type of students who are inclined towards memorizing the exercises through repetition acquires the knowledge 95%, while the

**Table 1: Matrix of outcomes for Method No. 01**

|                            | Students      |               |
|----------------------------|---------------|---------------|
|                            | Method No. 01 | Method No. 02 |
| Academician- Method No. 01 | 100           | 75            |

second type of students who gets saturated due to monotones repetition acquires the knowledge 75%. This is represented in matrix of outcome as above.

If the academician decides to adopt method- 01 along with 10 problems of different type, then the first type of students who are inclined towards memorizing the exercises through repetition will show poor performance due to frequent change in problems. The first type of students will get confused and will find difficult to cope up with frequent change of problems. Table 02 shows the outcome of this exercise:

**Table 2: Matrix of outcomes for Method No. 02**

|                            | Students      |               |
|----------------------------|---------------|---------------|
|                            | Method No. 01 | Method No. 02 |
| Academician- Method No. 02 | 65            | 100           |

**Table 3: Matrix of combined outcomes for both Methods**

|                           | Students      |               |
|---------------------------|---------------|---------------|
|                           | Method No. 01 | Method No. 02 |
| Academician-Method No. 01 | 100           | 75            |
| Academician-Method No. 02 | 65            | 100           |

The matrix provided above reflects the conflicting circumstances which the academician has to handle due to unpredictability and variation in responses which varies from person to person. As the number of participating students may affect the results obtained by the academician, 45 students of first and 15 students of second category were considered. Thus the results of method no. 1 are calculates as below:

$$45 \times \left( \frac{100}{100} \right) + 15 \times \left( \frac{75}{100} \right) = 56.25 \quad (01)$$

of 60 students having good results,

Whereas the results of method no. 2 is,

$$45 \times \left( \frac{65}{100} \right) + 15 \times \left( \frac{100}{100} \right) = 44.25 \quad (02)$$

of 60 students having good results,

In the above situation method no. 01 is better as compared to method no. 02. However, if in the same class 15 are the students of category 1 and 45 are the students of category 2, then the whole analysis will change.

$$15 \times \left( \frac{100}{100} \right) + 45 \times \left( \frac{75}{100} \right) = 48.75 \quad (03)$$

$$15 \times \left( \frac{65}{100} \right) + 45 \times \left( \frac{100}{100} \right) = 54.75 \quad (04)$$

of 60 students having good results for method no. 2,

In above combination of students now method no.2 is better than method no. 1. Thus depending on the proportion of type of students in the class, the method needs to be chosen.

### 3. Case study (Quantitative Techniques in Management, first year)

For more critical analysis, five teams of students studying MBA in the 'School of Management' of 'SAGE University' are considered. Students of 'School of Management' are chosen for analysis because this course is having heterogeneous mix of students with graduation in Commerce, Science and Engineering. Total 05 groups of students from first year were analyzed. The students were divided in two categories; graduates in commerce and graduates in science.

**Table 4: Variation in academic strategy due to variation in number of students of Type 01, Type 02 & Combined method**

|         | Number of graduates in |         | Chosen method |               | Combined method |
|---------|------------------------|---------|---------------|---------------|-----------------|
|         | Commerce               | Science | Method No. 01 | Method No. 02 |                 |
| Team 01 | 100                    | 30      | 110/130       | 90/130        | 109/130         |
| Team 02 | 40                     | 90      | 100/130       | 115/130       | 109/130         |
| Team 03 | 70                     | 60      | 116/130       | 80/130        | 109/130         |
| Team 04 | 54                     | 76      | 116/130       | 108/130       | 109/130         |
| Team 05 | 78                     | 52      | 101/130       | 75/130        | 109/130         |

Now the question arises, that can we find out the right combination of method no. 01 and method no. 02 so that the academician can obtain the best possible results for any class. Thus now we have to formulate the problem in such a way that the academician will obtain the best results for optimum combination of method no. 01 and method no. 02 irrespective of mix of type 1 and type 2 students.

There can be two strategies in this game situation;

- 1) Each side will have two strategies &
- 2) The loss happened to one side must be equal to the gain of the other side.

This will result that the total of gain and loss will be zero. As per the rules of Game Theory following combination will be the best for obtaining the right proportion of mixed strategy,

i. The difference of the values in the first column and in the second column are taken

ii. The results are expressed as absolute values written in reverse order as percentages in Figure No. 01 as below,

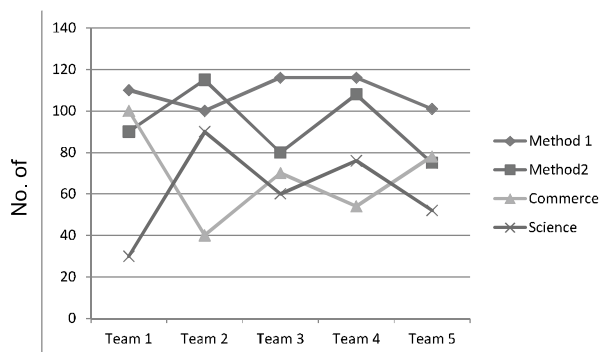


**Fig. 1: No of students appeared & passed in the examination**

For the optimum mixed strategy, the percentage ratio defines the frequency of application for the method no. 01 and method no. 02.

$$|100 - 75| = 25 \quad (05)$$

$$|65 - 100| = 35 \quad (06)$$

$$35:25 = 7:5$$

Irrespective of mix of students of type 1 and type 2, this is the proportion with which we have to apply method no. 01 and method no. 02 in-order to obtain the best results. In reality this exercise will be repeated four times for both the method.

For this situation the academician's result for first type of students will be,

$$\frac{(7 \times 100) + (5 \times 65)}{7 + 5} = 85.42\% \quad (07)$$

For the second type of students,

$$\frac{(7 \times 75) + (5 \times 100)}{7 + 5} = 85.42\% \quad (08)$$

Irrespective of combination of students, in this case the results will be 85.42%.

In Team 04 (from Table- 04) there are 40% students of Type 01 and 60% students of Type 02, so the combination will be 4:6. The results of this situation can be tabulated for the academician's pure strategies (by multiplying to figures in columns by 0.4 and 0.6)

**Table 5: The new results for academician's pure methods**

|                           | Students      |               |
|---------------------------|---------------|---------------|
|                           | Method No. 01 | Method No. 02 |
| Academician Method No. 01 | 42            | 44            |
| Academician-Method No. 02 | 27            | 59            |

Using the same mixed strategy developed for the academician earlier i.e. 7:5, for the students of Type 01, we will get the following results;

$$(7 \times 42 + 5 \times 27) / (7 + 5) = 35.75\% \quad (09)$$

For the second type of students;

$$(7 \times 44 + 5 \times 59) / (7 + 5) = (308 + 295) / 12 = 60.3 = 50.25\% \quad 83.65\% \quad (10)$$

In the above case obtained result of 83.65% is the best possible result. The Method 01 of pure strategy resulted into  $116/130 = 89.23\%$  good results and the Method 02 of pure strategy provided  $108/130 = 83\%$  good results.

By adopting pure method, the academician is obtaining the 83.65% results; which may not be the best possible results for any combination of students. But it is also clear that for any worst possible combination of Type 01 and Type 02 students, the results will never go below 83.65%, till he adopts best method. Following are the results shown in Figure No. 02 using different methods,

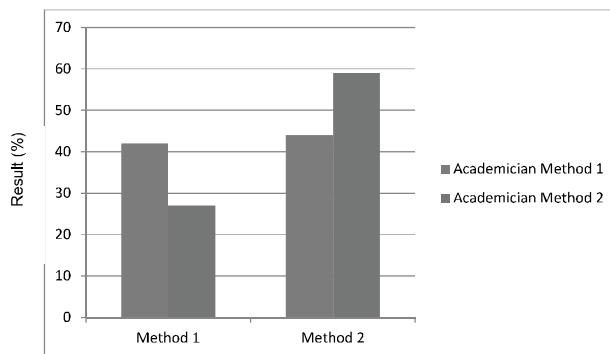


**Fig. 2: Variation of results using Method 1 & Method 2**

**Table 6: Advantage to academician while using different methods**

|         | Chosen method |               |                             |
|---------|---------------|---------------|-----------------------------|
|         | Method No. 01 | Method No. 02 | Combination of both methods |
| Team 01 | 84.62%        | 69.23%        | 83.65%                      |
| Team 02 | 77%           | 88.46%        | 83.65%                      |
| Team 03 | 89.23%        | 61.54%        | 83.65%                      |
| Team 04 | 89.23%        | 83.08%        | 83.65%                      |
| Team 05 | 77.70%        | 57.69%        | 83.65%                      |

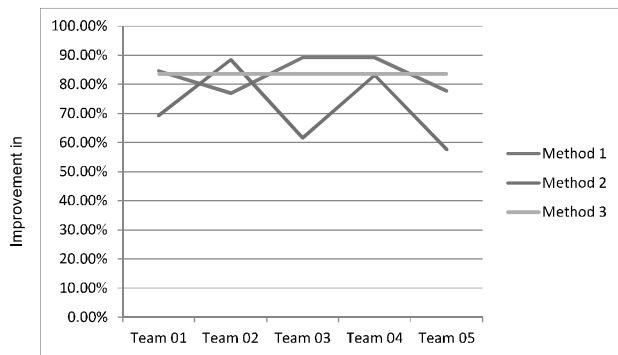


**Fig. 3: Result improvement with combination of methods**

For the first year of Master of Business Management (MBA), for the subject Quantitative Techniques in Management, to obtain the breakeven point the same mixed method is adopted. The results are presented as below,

**Table 7: The result matrix for the subject Quantitative Techniques in Management**

|                           | Students      |               |
|---------------------------|---------------|---------------|
|                           | Method No. 01 | Method No. 02 |
| Academician-Method No. 01 | 100           | 60            |
| Academician-Method No. 02 | 45            | 100           |

As the students under consideration are post graduate students who are more focused and learned to effectively use their memory to remember the topics taught by the teacher, so we cannot adopt methods chosen for school students. Thus academician should evolve the best possible mixed method as it is difficult for these students to precisely classify as Type 01 and Type 02 students.

Table No. 06 highlights the advantages for the academicians by using the combination of method No. 01 & Method No. 02. The use of combined method results in improvement in performance of the students or the participants irrespective of their academic background. From Table No. 07, it is explained that, for a particular pattern of study adopted by the students the exclusive use of certain technique will be giving high results.

#### 4. Conclusion

In teaching learning process choosing the right pedagogical method for obtaining the best solution is highly difficult as it involves large number of variables and multi facet circumstances. In addition to this planning of didactical activity is much demanding. For such complicated and conflicting

situations a planning model is provided by Game Theory.

In this study after real situations are simplified on larger extent it is observed that the best possible mixing of strategies provides highly reasonable solutions. It helps academicians to plan the didactical process well in advance i.e. before knowing the learning abilities and basic knowledge levels of the participant group of students.

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**Demographic Data of Students of  
'School of Management' of 'SAGE University'  
CLASS:- MBA (FIRST YEAR)**

| <b>Team No.</b>    | <b>Team member with academic background</b> | <b>No of Students</b> | <b>GRADUATED IN</b>                                                       |
|--------------------|---------------------------------------------|-----------------------|---------------------------------------------------------------------------|
| <b>TEAM NO. 01</b> |                                             |                       |                                                                           |
| TEAM NO. 01        | COMMERCE                                    | 72                    | COMMERCE<br>i.e. Group of Students admitted to MBA after completing B.Com |
| TEAM NO. 01        | SCIENCE                                     | 24                    | SCIENCE<br>i.e. Group of Students admitted to MBA after completing B.Sc   |
| <b>TEAM NO. 02</b> |                                             |                       |                                                                           |
| TEAM NO. 02        | COMMERCE                                    | 24                    | COMMERCE<br>i.e. Group of Students admitted to MBA after completing B.Com |
| TEAM NO. 02        | SCIENCE                                     | 72                    | SCIENCE<br>i.e. Group of Students admitted to MBA after completing B.Sc   |
| <b>TEAM NO. 03</b> |                                             |                       |                                                                           |
| TEAM NO. 03        | COMMERCE                                    | 48                    | COMMERCE<br>i.e. Group of Students admitted to MBA after completing B.Com |
| TEAM NO. 03        | SCIENCE                                     | 48                    | SCIENCE<br>i.e. Group of Students admitted to MBA after completing B.Sc   |
| <b>TEAM NO. 04</b> |                                             |                       |                                                                           |
| TEAM NO. 04        | COMMERCE                                    | 39                    | COMMERCE<br>i.e. Group of Students admitted to MBA after completing B.Com |
| TEAM NO. 04        | SCIENCE                                     | 57                    | SCIENCE<br>i.e. Group of Students admitted to MBA after completing B.Sc   |
| <b>TEAM NO. 05</b> |                                             |                       |                                                                           |
| TEAM NO. 05        | COMMERCE                                    | 57                    | COMMERCE<br>i.e. Group of Students admitted to MBA after completing B.Com |
| TEAM NO. 05        | SCIENCE                                     | 39                    | SCIENCE<br>i.e. Group of Students admitted to MBA after completing B.Sc   |

## Redesign of Digital Circuits course for enhanced learning

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**Abstract:** The paper presents the restructuring of course design and delivery, to attain the enhanced learning in Digital Circuits course through pedagogic practices and hands on experience in laboratory. The objective of the paper is to enhance the understanding of the course beyond the class room teaching. The traditional approach of course design, course delivery and course assessment provide less scope for better learning of courses. To address the limitations of traditional approaches, an Outcome Based Education (OBE) proposes many pedagogical practices. The paper proposes a framework to restructure the Digital Circuits course w.r.t.. to content delivery in the class, course projects and the reframing the laboratory experiments. The contents delivery is supported by expert lecture through videos, course project is aided by concept/prototype development and the lab is formulated to exercise multiple problems on a single topic. The students' attainment is measured and analyzed through examination results and feedback. The technical and professional outcomes are achieved through the proposed framework.

**Keywords:** Digital Circuits, alternate design, OBE, course design, course project, simulation.

### 1. Introduction

The quality of education is a key performance indicator for any institution specifically in the areas of teaching and learning. The process of learning should not be passive and also it should not be limited to an individual. Learning can be meaningful when an individual starts developing a capability of using the ideas and information, tests the given information and generates new ideas [1]. At the same time as students begin to ask out of box questions rather than simply answering the questions is the point of opportunity where the strategies of the faculty can be enhanced. A teaching can be said as effective when the procedures followed are appropriate and its purpose benefits the student learning [2]. In this paper we seek to address this aspect.

For learning to be successful, student's involvement is essential and as a facilitator the teacher has to perform the tasks of guiding and promote student interaction. In this paper we address the teaching-learning based strategy development for the Digital Electronics subject, Laboratory and course project. A demonstration of a concept where relevant example is solved in the class or laboratory and students are asked to develop a design for the given problem is regarded as a basic method.

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In this paper we see how a batch of around forty students are divided into smaller groups including two or a maximum of three students in a group and the strategies used to clarify the concept by making the students discuss or debate in the team to find the appropriate solution for the design and then tend to implement them further. This process also helps the students to interrogate with the fellow teams as to know what problem statement are the fellow teams working upon and analyse the design flow that these teams have used to arrive at the solution. This debate and interrogation with the co- groups along with the teacher's efforts to frame such relevant and brain storming question sets helps the students to find multiple solutions for a given problem. These solutions are cross verified by the help of simulation tools before implementing on the breadboard.

This methodology helps in making the student become active team-players. The same aspects are further enhanced where students are made to deploy their ideas as a part of course project, thus focusing on the ability of the student to divide the given task into different modules and share them among themselves, thus understanding the role of individual in carrying out the process and identifying themselves as role-players. These explorations help students to regulate themselves to new concepts and principles and also allow them to maintain equilibrium by understanding each other mutually [3].

During the process of such joint activities, students may have to articulate their opinions, predictions and interpretations [4]. Sometimes these peer collaborations may result in conflicts when students disagree in approaches or interpretations of their team-mates while arriving at the solution to the task. This can also be taken as a part of learning as the students co- construct shared knowledge while solving a problem by understanding and complimenting on each other's ideas [5].

The paper demonstrates:

- In-depth learning in digital circuit course using pedagogical practices such as videos in the class.
- Paradigm shift in the course learning through course project to provide better exposure to simulation and prototype development.
- The redesign of laboratory plan to frame problem statements on the same topic in order to provide

more exposure to varieties of problems.

The rest of the paper is organized as follows. Section 2 provides Literature survey, Section 3 provides the proposed methodology, Section 4 provides discussions the results and conclusions are provided in Section 5.

## 2. Literature Survey

In order to tackle with the real-life technical problems, students need to develop an art of critical thinking. Many researchers have highlighted the need and importance of the thinking ability [6]. Imposing the thinking ability within the students makes them extract the information by proper analysis which includes removal of biased or even false contents and hence sorting out only the subjective information [7]. According to the discussion done in [8] students need to be instructed on how to use the tools for enhancing their abilities and helps them to explore similar tools to perform the tasks in hand thus enabling them to acquire knowledge.

As per the discussion in paper [9] it is said that making receive effective information and to practice deliberately can improve the skills and this is also associated with receiving appropriate feedback by the students. This practice is usually followed and without making the students to explore and inculcate the habit of thinking and analyze the related concepts would be a drawback of teaching. As per [10] students need to be scaffold by the teachers to bring out their thinking with respect to their learning from various perspectives and make them deploy the task with a structured presentation. Paper [11] highlights on the thinking levels given by revised Bloom's taxonomy that needs to be incorporated by the students. There are six such levels which are listed as follows:

- Knowledge
- Conceptual understanding
- Implementation
- Justification which is followed by analysis
- Regulating their analysis by self evaluation
- To create the given task in hand.

The authors in the paper [12] say that though the

aspects of critical thinking and making students think creatively are complementary to each other, but both these skills are in favor of the student and encourage the independent thinking ability of the student. The discussion in papers [13, 14] is about incorporating skills in the students in-order to enhance their thinking capabilities. Some of these skills are,

- Logical argument with proper evidence
- Analyzing the quality of the given sources
- Synthesizing the results from variety of sources
- Reasoning from general to specific (deduction)
- Reasoning from specific to general (induction)
- Solving the problems in hand by knowing the given specifications
- Evaluating their own decisions from different view points

Author in [15] suggests that a physical phenomenon can be made to understand conceptually by visualizations through demonstrations and experimenting in laboratories. But this paper does not specify regarding the student development in several aspects. As per the author's view given in the paper [16] scaffolding is the process where students are supported till they are able to apply new skills and develop the strategies without any further guidance by the teacher and this has been regarded as an excellent method in enhancing the thinking ability of the student. In [17] co-operative learning is emphasized which enables the knowledge of scaffolding by making the students discuss and interact in a systematic way. Paper [18] says that students can be asked to identify the logic or the origin of the conceptual idea by posing the questions in that regard.

As per the analysis made it says that scaffolding based activities help the students to develop the expertise in the following:

- Solving problems by capacity of cognitive thinking
- Ability to appreciate, value and care by developing the affective capacity
- Capability to perceive and apply physical skills

- Co-native ability which helps them to commit, decide and act.

### 3. The Proposed Framework

The proposed framework is practiced to teach the undergraduate courses of III semester for the School of Electronics and Communication Engineering and Department of Electrical and Electronics Engineering. The Digital Circuits course is restructured to enhance the practical exposure of the students towards the theoretical concepts. The digital circuits course is structured as classroom teaching for 4 credits and laboratory experience for 1 credit. The proposed framework was practiced for strength of 370 students. The proposed structured for the course is discussed as follows.

#### A. Classroom Teaching

The classroom teaching is categorized as content delivery and course project.

##### 1) Content delivery:

The course contents are retained and mode of content delivery is restructured so as to enhance the teaching learning process. The traditional mode of content delivery of using chalk and talk was aided by expert lecture through videos. The content was delivered with real-time examples for formulating the problem and providing an engineering solution for the same. The real-time example was scenario based which helped the students' approach towards problem solving.

The Table I provides the traditional problem statements and the proposed statements.

##### 1) Evaluation:

The students are evaluated for their understanding of the course thrice in a semester. The evaluation is twice through continuous internal examination (CIE) and once through semester end examination (SEE). The traditional evaluation was adhered to only PO-1 of ABET which was to apply basic engineering knowledge. The restructured course addresses PO-2, PO-3, and PO-5. PO-2 caters to demonstrate an ability to formulate a solution plan and methodology for an engineering problem. Whereas PO-3 provides an ability to generate a diverse set of alternative design solutions. Finally, PO-5 demonstrates an ability to

**Table 1: The traditional problem statements and the proposed statements.**

| Traditional Statements                                                                                                                                                             | Proposed Statements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Find<br>The minimal<br>sums for<br>the<br>following<br>Boolean<br>Expression<br>using K-Map<br>reduction<br>technique.<br>$P=f(w,x,y,z)$<br>$=$<br>$\sum m(1,5,6,7)$<br>$+dc(0,4)$ | Two motors, $M_2$ and $M_1$ , are controlled by three sensors, $S_3$ , $S_2$ , and $S_1$ . One motor, $M_2$ , is to run any time when all three sensors are ON (true). The other motor is to run whenever sensors $S_2$ or $S_1$ , but not both, are ON and $S_3$ is OFF. For all other sensor combinations where $M_1$ is ON, $M_2$ is to be OFF, except when all three sensors are OFF, both motors must remain OFF. Identify a technique that cannot be programmed and that is used for less number of variables, to provide minimal sums. |
| Design a<br>Synchronous<br>Mod-6<br>Counter using<br>clocked JK<br>Flip-Flops                                                                                                      | Design a system to provide status of the number of people present in a seminar hall. The maximum occupancy of seminar hall is 7 members. The status is checked six times in an hour at equal intervals. It is observed that, initially it was empty. After these four members entered the hall, then one member left, and then two more entered. Again three members left, then five entered at the end. Store this status and demonstrate the occupancy of the hall continuously at all intervals. Use Flip flops with two inputs.           |

identify/ create modern engineering tools, techniques and resources. The results obtained in traditional mode of course delivery did not highlight the student's attainment in formulating and analysing the engineering problem. The proposed course design emphasizes the student's performance in PO-1 as well as PO-2.

## 2) Course Project:

Project is a universally used word in engineering, defined as a unit of work carried out based on the provided specifications. The projects will have various structures w.r.t. size of project, timeline of project, complexity of projects etc. Projects relate to the fundamental concepts and techniques of an engineer's discipline. Mini projects involve one area of engineering specialization, but major projects will

be multidisciplinary, not only involving engineers from different specializations, but other professional and non- professional personnel also. Successful completion of projects in practice requires the integration of all areas of an Engineer's undergraduate training.

Course project is a component associated with the teaching of a course. Course projects are defined to occupy few weeks for implementation and is directed towards the application of knowledge. Project-based learning is usually accompanied by subject courses to enhance skills such as time management, resource management, group learning and discussions, self directed documentation, budget requirements, optimization of design, oral and written presentations. Hence the chalk and talk mode of content delivery limits the students understanding and imagination and enhances the above discussed skill set. The digital circuit course is framed so as to address many more aspects of circuit design and simulation. A proactive treatment is initiated for improved level of understanding of course content with better exposure to practical issues.

The Table II provide the problem statements for the course project. The statements are framed such that the students are able to apply the knowledge gained the course and get better exposed to the formulation of objectives for the stated problem and implementation of the same.

**Table 2. Problem statements for course project**

| Sl. No. | Few of the proposed statements                                     |
|---------|--------------------------------------------------------------------|
| 1       | Design and implement an IC tester for testing the basic gates.     |
| 2       | Design and implement 4 bit binary divider using Vedic mathematics. |
| 3       | Design and implement a 4 digit lottery number generator.           |

## 4) Competency addressed in the Course and corresponding Performance Indicators

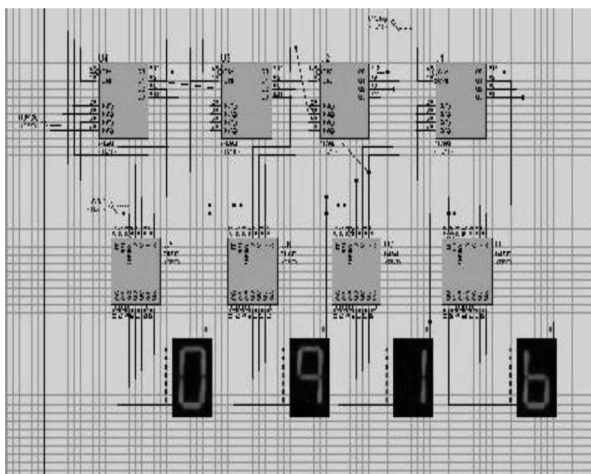
The Table III provides the information about the competency addressed in the course through the listed performance indicators. The students are focused towards the attainment of problem formulation, identifying multiple solutions, optimizing the design w.r.t. cost, components and space, simulation of the optimized circuit, developing the prototype on printed circuit board.

**Table 3. Competency addressed in course project**

| Competency                                                                    | Performance Indicators                                                                                         |
|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| PO 2.2 - Formulate a solution plan and methodology for an engineering problem | PO 2.2.2 - Identify, assemble and evaluate Information and resources.                                          |
|                                                                               | PO 2.2.3 - Identify Existing                                                                                   |
|                                                                               | processes/solution methods for solving the problem, including forming justified approximations and assumptions |
| PO 3.2 - Generate a diverse set of alternative design solutions               | PO 3.2.1 - Apply formal idea generation tools to develop multiple engineering design Solutions                 |
| PO 5.1 - Identify/ create modern engineering tools, techniques and resources  | PO 5.1.1 - Identify modern engineering tools, techniques and resources for engineering Activities              |
| PO 10.1 - Comprehend technical literature and document project work.          | PO 10.1.2 - Produce clear, well-constructed, and well-supported written engineering documents                  |

#### 5) Sample project snap shots and evaluation:

The course project is evaluated for the above performance parameters. Figure 1 shows the simulated circuit for the lottery number generator for 4 digits. The same circuit is implemented on printed circuit board as shown in Fig. 2

**Fig.1: Simulated circuit for the sample course project**

#### B. Laboratory experience

The objective is to enhance the learning of the course beyond the traditional mode of conduction of

experiments. Where, lab design, conduct and lab assessment provide less scope for in depth learning of courses. Outcome Based Education (OBE) is an effort to overcome limitations of traditional education by using progressive pedagogical models, ideas, to meet student outcomes of ABET.

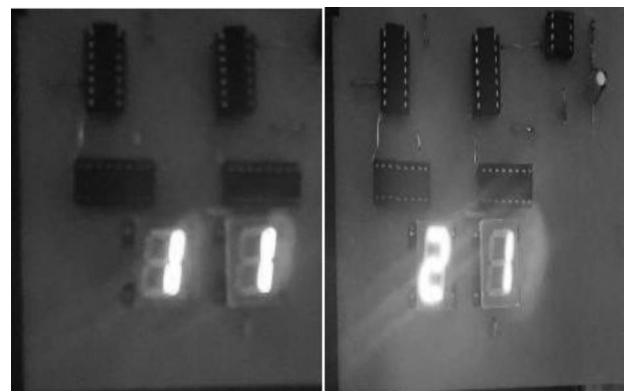
#### 1) Laboratory categorization:

To meet the expectations of present engineering education, the designs of Digital Circuits lab experiments are categorized as demonstration, exercise, structured experiments.

**Demo Experiments:** The demonstration experiments are designed basically to get exposure regarding the major components used in the laboratory and to apply few basic concepts.

**Exercise Experiments:** The exercise experiments are given to provide experiential learning to the students in basic working of modules, components and small systems.

**Structured enquiry experiments:** The structured enquiry experiments are given to provide an exposure to identify solution to given problem, existence of alternate solutions and to choose optimal.

**Fig. 2: Implementation of designed course project on PCB.**

The Digital Circuits laboratory comprises of total 10 experiments out of which 2 are demonstration type, 6 are exercise type and two are structured type experiments. The paper concentrates on restructuring exercise and structured enquiry experiments. Each of the exercise and structured enquiry titles are framed with 6-10 problem statements as shown in Table IV. A batch of 40 students is formed for laboratory exercise at a time supervised by faculty members. Different statements will be given to a sub batch of 2 students

**Table 4: List of problem statements for a single title.**

| Few of the proposed problem statements |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Title :                                | Design and implement n bit magnitude Comparator                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Statements:                            | <ul style="list-style-type: none"> <li>• Design 6 bit binary comparator using only one 4 bit comparator i.e. 7485.</li> <li>• Design 5 bit binary comparator using only one 4 bit comparator i.e. 7485.</li> <li>• Design 6 bit binary comparator using only two 4 bit comparators i.e. 7485.</li> <li>• Design 5 bit binary comparator using only two 4 bit comparators i.e. 7485.</li> <li>• Design 1.2.3.4 bit binary comparators using only one 4 bit comparator i.e. 7485.</li> <li>• Design 1 bit and 2 bit binary comparators using only basic gates.</li> <li>• Design 1 bit and 2 bit binary comparators using only NAND gates.</li> </ul> |

**Table 5. Competency addressed in laboratory**

| Competency                                                                                                     | Performance Indicators                                                                                                                           |
|----------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| PO 4.1- Conduct investigations of technical issues consistent with their level of knowledge and understanding. | PO 4.1.2- Relate modern engineering experimentation including experiment design, system calibration, data acquisition, analysis and presentation |
|                                                                                                                | PO 4.2.3- Identify multiple solutions, and choose an appropriate design for the problem.                                                         |
|                                                                                                                | PO 4.1.4- Establishes or validates a relationship between measured data and underlying physical principles                                       |
| PO 5.2- Select and apply discipline specific tools, techniques and resources                                   | PO 5.2.2- Demonstrate proficiency in using discipline specific tools                                                                             |

for design and implementation. The students will collect the statement one week prior to the scheduled dates. On The scheduled date the students will design the circuit on the paper, simulate and implement the same for functional verification

#### 1) Evaluation in laboratory

The students are evaluated for the competencies in table V through the predefined rubrics. The outcome of this mode of laboratory experimentation:

- Avoids copying the design from friends.

- Prevents mass design and simulation
- Avoids the last moment preparation for laboratory.

#### 4. Discussions and Results

This section provides the discussions on the results and feedback for the proposed framework and its implementation.

##### A) Feedback of students

Q1. To what extent expert lecture has enhanced the overall learning of Digital Circuit Course?

a. 80-100 % b. 60-80 % c.40-60 % d. less than 40 %

Q2. The activity has helped in gaining proficiency in using the simulation tool.

a. Strongly Agree b. Agree

c. Neutral d. Disagree

Q3. To what extent project-based learning helped in overall understanding of the course?

a. 80-100 % b. 60-80 % c.40-60 % d. less than 40 %

Q4. Has multiple design statements for a single experiment helped in enriching the design concept?

a. Yes b. No

Q5. Time allocated to carry out the entire course was enough?

a. Yes b. No

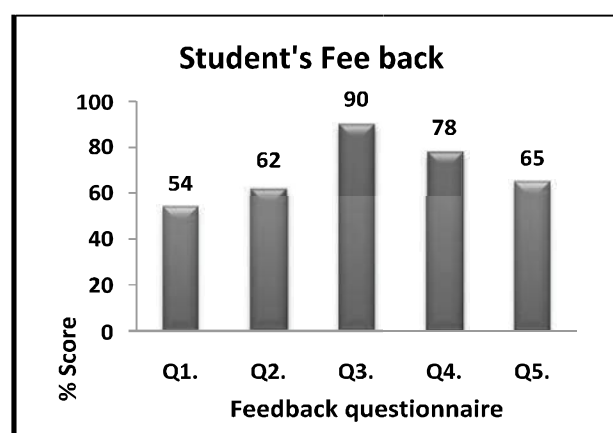


**Fig. 3: Feedback Score for overall course design and delivery**

A common feedback was taken at the end of the theory and laboratory course. Out of 370 students, 325 students have given the feedback. In the Fig.3 the percentage score of feedback given by students is depicted for the highlighted option in the questionnaire. The feedback was collected through goggle forms. More than 50% of the students said that expert lectures have enhanced their overall learning. 62% students strongly agree that they have gained proficiency in using the simulation tool after undergoing this process. 90% of students expressed that project-based learning has improved the overall learning. Only 18% students said that they are less confident in designing the complete system. Around 35% students have raised a concern about the time allotted to carry out the complete course. The feedback questionnaires are presented below.

#### B) Attainment of performance indicators

The proposed framework addressing the identified performance indicators are measured through In Semester Assessment Continuously End Semester Assessment. The individual performance indicator is set with a threshold value based on the previous experience. The overall attainment of the performance indicators is depicted by the graph in Fig. 4. The performance is satisfactory but, provides ample scope for further improvement. Few PI's are attained to the satisfaction level, but few are not up to expectations. The proposed framework provided the course instructor to evaluate the skill set of students such as problem formulation, identifying multiple solutions, optimizing the design w.r.t. cost, components and space, simulation of the optimized circuit, developing the prototype on printed circuit board individually. The course instructor could identify the strengths and weaknesses of students and reframe the course for further improvement.

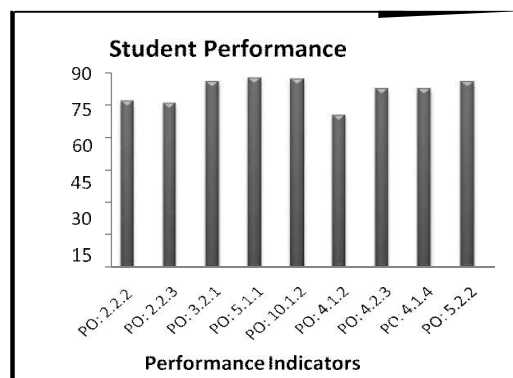


**Fig. 4: Overall attainment of performance indicators over a academic year**

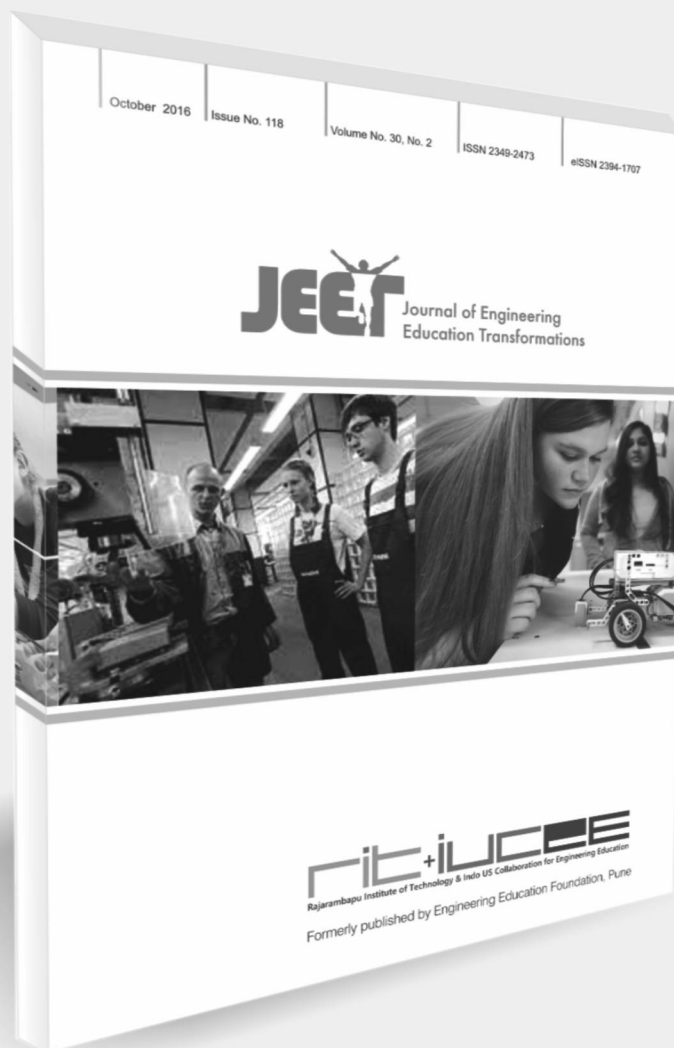
## 5. Conclusion

The paper presented the course redesign and delivery, to attain the enhanced learning in Digital Circuits course through pedagogic practices and hands on experience in laboratory. The framework enhanced the understanding of the course beyond the class room teaching. To address the limitations of traditional approaches, an Outcome Based Education (OBE) proposed provides scope for using many pedagogical practices. The paper proposed a framework to restructure the Digital Circuits course w.r.t. to content delivery in the class, course projects and the reframing the laboratory experiments. The contents delivery is supported by expert lecture through videos, course project is aided by concept/prototype development and the lab is formulated to exercise multiple problems on a single topic. The students' attainment is measured and analyzed through examination results and feedback. The technical and professional outcomes are achieved through the proposed framework.

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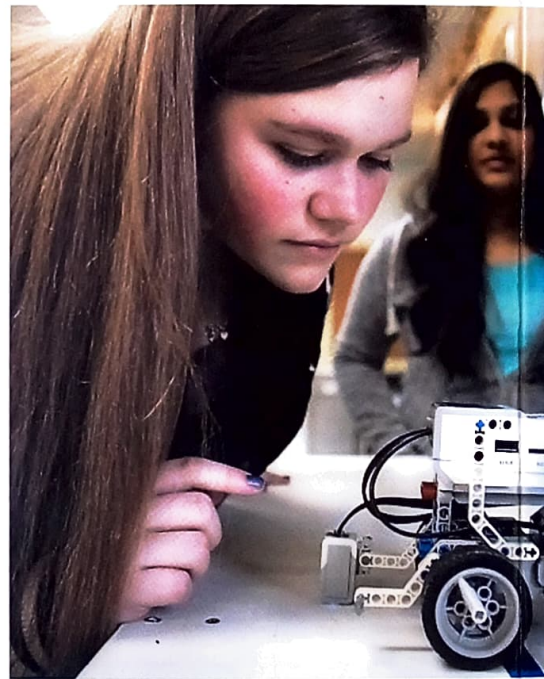


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