Systematic and Rigorous Use of Feedback to Enhance Learning in Engineering Classes

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Abstract: Feedback is among the most common features of successful teaching and learning. Feedback aims to reduce the gap between where the students are and where they are meant to be. In order to bridge this gap, teachers must incorporate feedback in classroom effectively. There is a need to understand different ways in which feedback can be provided in classroom. There is also a need to identify and implement simple yet systematic procedure to provide regular and transparent feedback in classroom. This study presents deliberate use of spaced questioning to understand how to take full benefits from feedback in the classroom. Feedback is summarized based on the errors committed by the students. Instead of considering the errors simply as deficit of knowledge or inability of students to think correctly, they can be treated as opportunities to bridge the gap of what students know and what they should know. Knowing and acknowledging these errors is the key contribution of a teacher, which can be attained through feedback in classroom. The participants in this study were first year engineering students of 14 classes, enrolled for the Engineering Mechanics course. An ICT tool named MKCL SuperCampus, was used to pose questions and to track real time individual performance in the classroom. The use of the ICT tool provided an easy and fearless environment for students to participate comfortably, thereby motivating them to make and learn from errors and to engage more while learning in classes.

Keywords: Information and Communication Technology (ICT), Teaching-Learning, Instruction, Formative assessment, Learning outcomes

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1. Introduction

Feedback is central to the development of student learning. It is observed that after completion of any typical instruction or lecture by a teacher, most students are less likely to grasp all the concepts taught by the teacher. Teachers often experience such learning gaps created due to incomplete information, misconception or lack of thorough understanding. Such learning gaps, if left unaddressed can lead the students to errors thereby resulting in not achieving the success criteria of learning outcomes. The purpose of feedback is to know these errors and address them at the earliest stage of learning cycle. A fundamental consideration about feedback is that, it can be provided by teachers only after completion of instruction.

Sadler, 1989, defined feedback in a particular way to highlight its function in formative assessment to reduce the gap between where the student is and where he or she is meant to be [1]. He argued that this gap can be reduced if there is a provision for a direct, authentic and transparent evaluative experience for the students. Intuitively, feedback can be universally beneficial. Pashler et al., 2005, in an experiment from language learning domain, found that immediate feedback, after an incorrect response improved final recall by 494% [2]. Butler et al., 2008, have shown that when their participants provided correct responses to multiple choice questions with low confidence ratings, immediate feedback substantially improved their recall [3].

Hattie, 2012, has discussed feedback at four levels – task level, process level, self regulation level and at self level [4]. These four levels are identified to address the three questions of any learning process. These three questions are – where is the learner going, how is he/she going and what is the next step to improve his/her progress. To address the first question, the teacher needs to have a clear understanding of the goals of a lesson and these also need to be communicated properly to the learners. Rapid formative feedback helps in the attainment of challenging goals in two ways – 1) It can help students to keep a track of their performance towards these goals. 2) Feedback allows both students and teachers to appropriately set challenging goals after achieving the earlier ones. Wiliam and Thompson, 2007, have emphasized the need of integrating formative assessment with learning in order to

find the most cost effective ways of improving student achievement [5]. In a collaborative study taken up with a group of 24 teachers of a secondary school, Wiliam et al., 2004, provide firm evidence that formative assessment does produce tangible benefits in terms of externally mandated assessments [6]. To address the second question about how a learner is progressing, Black et al., 2003, have discussed specific practices which were effective for assessment of learning [7]. The five key ideas that can make learning more efficient are communicating learning intentions and criteria of success, classroom discussions using challenging questions or learning tasks, providing appropriate feedback and creating awareness among learners about responsibility of their own learning. Chan, 2006, has examined the effects of different evaluation feedback on students' efficacy in learning, to show that formative and self referenced feedback was highly beneficial [8]. Such feedback enabled the students to perceive a sense of control over their progress. Hays et al., 2010, have reported an experiment in which total time for learning was fixed, thereby creating a trade-off between spending time receiving feedback and spending time on other learning activities [9]. The main finding of this study was that when time was allocated to retrieval attempts, instead of immediate feedback after correct responses, learning was enhanced. The third question about what is the next step in learning, can lead to deeper understanding of finding different strategies /methods to complete a task. This question about "where to next?", also helps a student to understand what is and what is not understood.

Conventional thinking suggests that praising a learner as an individual or praising his/her traits is beneficial for boosting self confidence and encouraging mastery oriented qualities. In a typical feedback intervention, teachers are very likely to include praise along with the particular feedback. A teacher usually believes that by offering some support in terms of a praise, he/she would make the learner more comfortable, thereby expecting the student to engage in a better way. In an interesting study by Wilkinson, 1980, relationship of teacher praise to student achievement is discussed [10]. The data in this study reveals that teacher praise has little, if any, relationship to student achievement. Kluger et al., 1996, in their rigorous study have concluded that feedback interventions without praise provided a greater effect on achievement than those feedback interventions which incorporated praise [11]. They have also reported wide variability in the effects of feedback. Kessels et al., 2008, have reported that positive feedback about academic performance led to lower engagement and effort by learners, thereby creating a threat to crucial aspects of their identity [12]. The findings reported about praise by Kamins and Dweck, 1999, also contradict the conventional thinking of teachers [13]. These findings suggest that praising a learner as a whole or praising his/her ability, hinders the very purpose of praise that it was intended for. Conventional thinking also warns us against globally criticizing a learner instead of focusing on specific behaviour. Hyland and Hyland, 2001, present a detailed analysis of written feedback in which praise was the most frequently employed and was used to soften criticism and suggestions [14]. The study infers that learners failed to understand their teachers' comments due to their indirectness thereby leading to incomprehension and miscommunication. Results presented by Skipper and Douglas, 2011, suggest that praising effort is likely to have a negative effect when students are not successful or they begin to fail [15]. The most detrimental effect of praise for students who might be successful or unsuccessful is that, it tends to make the students dependent on the presence of praise and helpless in its absence.

Despite its importance, the research on feedback reveals that the students are often dissatisfied with the feedback they receive due to various reasons. In a study carried out by Carless, 2006, it is argued that the feedback given by teachers to the whole class after the assessment process, is mostly not received by the students and used in revision of work [16]. No single student believes that a feedback being given for the whole class is actually meant for him/her. Goldstein, 2006, provides insights about another dimension of feedback types – the narrow and the broad type of feedback [17]. Narrowly drawn feedback is focused on a very small number of specific features whereas a feedback with a broad base is typically unfocussed due to the large range of errors being covered. The learners often find feedback unreasonable or confusing or not very useful and hence do not tend to act upon it for self improvement. Higgins et al., 2001, have reported that the inability of students to understand the feedback comments correctly is commonly decided by two main factors [18]. The first factor is the students' perception of how impartial, trustworthy and proficient the feedback provider, the teacher is. The second factor is associated with the importance of relevance of content for the student and his/her level of investment of effort.

Failures or learning from errors are very critical opportunities and should not be left untapped. Students make errors when either they posses incomplete knowledge or are not enough proficient or have some misconceptions. Errors explicitly convey the gap between what we know and what we could know. Nickerson, 1998, has reported two types of feedback – Confirmation based and Disconfirmation based [19]. Feedback given to disconfirm a certain misconception, erroneous understanding or assumption, makes a greater change, provided it is convincing and is accepted. However the natural tendency of a learner as well as a teacher is to seek a confirmatory feedback of interpretations and understanding. Disconfirmation feedback is powerful not just to address faulty interpretations, but also to improve long term retention. Kang et al., 2007, found that when learners were provided with feedback for incorrect/incomplete short answers, the learners exhibited better retrieval effort in the subsequent assessment [20]. Another study undertaken by Peeck et al., 1985, also confirms a significant positive effect of feedback on incorrect initial responses as compared to feedback on correct responses [21].

Feedback in classes creates a possibility for mutual meaningful interactions between learners and the teacher. Hamre, et al, 2013 have shown positive associations between classroom interactions and student outcomes and have identified effective classroom practices using the Teaching Through Interactions (TTI) framework [22]. Pianta, 2016, has reported that interactions must be frequent, consistent and also meet certain quality threshold to manifest the positive effects in student outcomes [23].

Although the current literature provides useful insights into the role of feedback in student learning, its use in higher technical education is still underexplored. This paper summarizes the systematic and rigorous work of employing feedback in first year engineering classes. The two objectives of the study were –

- To understand the impact of feedback on student learning for one first year engineering course.
- To identify and adopt an instructional support system to implement feedback intervention effectively.

2. Methodology

The participants of this study were 576 (out of 742) first year engineering students of 14 classes, who gave consent to participate in this study. The typical strength of an engineering class is 60.

Although feedback is among the most powerful moderators of learning, its effects are highly variable. For an effective implementation of this approach of feedback intervention in classes, this study was planned in three phases-

- Phase I: Confirmation of the need and feasibility of this approach in first year engineering classes.
- Phase II: Preparation of challenging questions for the selected course.
- Phase III: Identification and implementation of the strategy for effective feedback intervention.

A. Phase I

In this phase, a confirmation about the need and feasibility of implementation of feedback intervention was done by conducting an initial survey of the participating students. In real world educational situations, the time available for teaching learning is the allotted classroom time and this available time is often constrained. If the feedback intervention was to be implemented, it was necessary to find whether the entire classroom time is effectively utilised by the teacher and whether the students are engaged in learning for this complete duration. The survey questions were therefore addressed to find out typical attention span of the students and the reasons, if any, for not being able to engage for complete duration of classroom time. Fig.1 shows the typical attention span of students in a classroom time of one hour. The typical attention span of only 17.02% students was for the entire duration. Since 74% students i.e. majority of them, had an attention span between 30 to 45 minutes, it seemed feasible for a teacher to spare around 15 minutes for feedback on responses of challenging questions. Since 83% students convey that their attention span is either 45 minutes or less, it indirectly also conveys that however strongly a teacher may claim effective utilisation of entire classroom time, it is never the same from the students' side. Hence if a teacher desires to utilize the classroom time most effectively, he/she should be aware of the typical reasons for the loss of attention. Fig. 2 shows the probable reasons for the loss of attention in a lecture. 78% (47.7% + 30.27%) students consider the long and continuous span of teaching as the significant reason for the loss of attention. This underlined the necessity to break the total classroom time into smaller spans of teaching. This necessity was seen as an opportunity for feedback intervention which served dual purpose of breaking the monotony of a lecture and of regaining student attention back to learning.

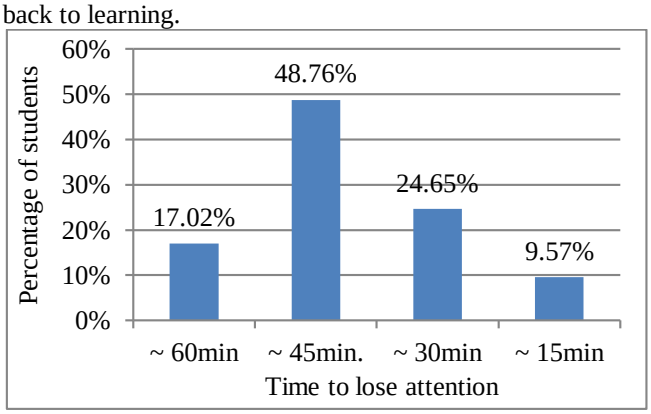

Fig. 1 Typical attention span of students

For the feedback intervention to be successful, the primary requirement for the teacher was to receive maximum, ideally all, student responses for the challenging questions posed by him/her. Only then the summarized feedback and the corrective action based on it would have been meaningful and effective. Hence the classroom behaviour with regard to students' natural and spontaneous initiative to respond to a teacher's question posed during a lecture also had to be investigated initially through the survey. Liu, 2001, has categorized the passive and active type of

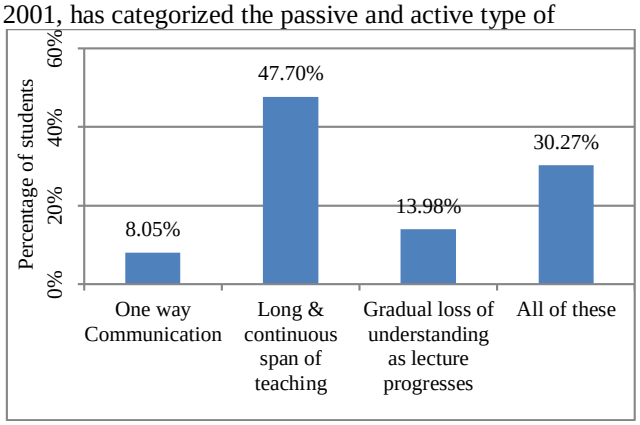

Fig. 2 Reasons for loss of attention during classroom time

classroom behaviors into four types- –full integration, participation under specific circumstances, marginal participation and silent observation [24]. Fig. 3 shows the students' initiative to respond to a teacher's question posed during a lecture. The behaviour of fully integrated students i.e. those who actively engage in each class most of the

times, were identified as those students who attempted to answer a question even if they were not certain about the correctness of the answer. The second type of behaviour of students with marginal engagement was identified with those who attempted to answer a question only if they were certain about the correctness of the answer. Students with circumstantial engagement were those who attempted to

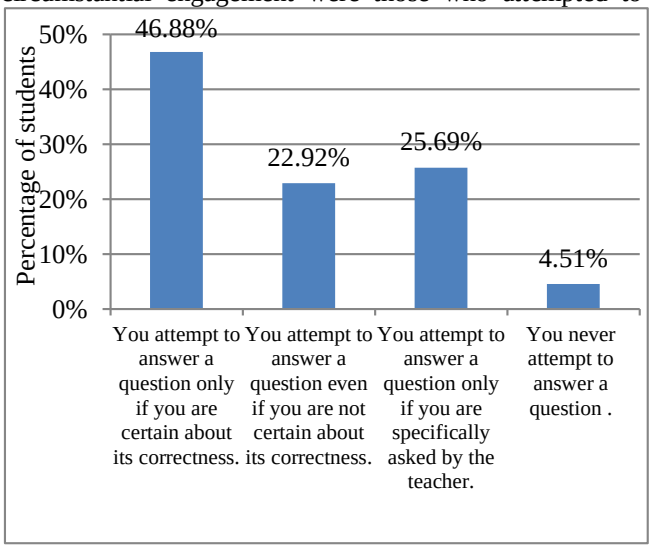

Fig. 3 Reasons for loss of attention during classroom time

answer only when a teacher specifically asked them to answer a question. Silent observers were identified from the category of those students who never attempted to answer a question. Only 22.92% students were identified as fully integrated ones who potentially could exhibit active classroom participation. Hence there was a need to motivate the rest of the majority students who could possibly exhibit an inherent reluctance to answer the questions asked by a teacher, for easily overcoming their passive classroom behavior.

Finally the selection of the course for implementing the feedback intervention approach was also based on the student opinion collected through this initial survey. Since the students perceived Engineering Mechanics as the most challenging course from the typical first year engineering courses, as shown in Fig. 4, it was decided to teach this course with feedback intervention approach in all 14 first year classes.

B. Phase II

A total of 9 teachers of Engineering Mechanics were supported over a six-month period in exploring and planning their feedback intervention approach. These 9 teachers along with 3 senior expert mentors were involved in preparation of the challenging multiple choice questions on various topics of Engineering Mechanics as per the teaching plan of the course. These questions were framed to deliver feedback at two levels – the task level and the process level. As discussed by Hattie, 2012, the feedback at the task level is highly useful to develop surface knowledge of a topic [4]. Being information focused feedback at task level deals with correct or incorrect responses and providing more or different information relevant to the task. It thus enhances the task knowledge of a novice learner. The feedback at the process level is aimed to ensure the proper understanding of different relationships between ideas/concepts and employing the task strategies. Feedback at the process level thus enhances deeper learning in comparison to the feedback at task level. It also helps a learner to develop his/her strategies for better learning and debugging errors, thereby reducing his/her cognitive load.

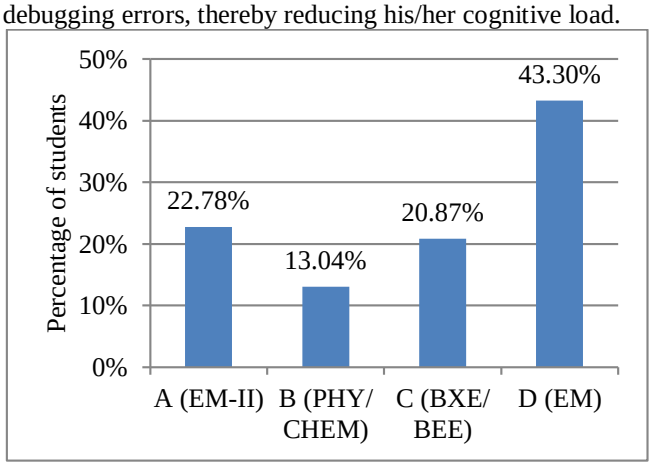

Fig. 4 Choice of most challenging first year course. (EM-II : Engg. Mathematics-II, PHY: Physics, CHEM: Chemistry, BXE: Basics of Electronics Engg., BEE: Basics of Electrical Engg., EM: Engg. Mechanics)

Table 1. Details of Questions of Engineering Mechanics

Unit No.	Name of Topic	No. of Questions for feedback at task level	No. of Questions for feedback at process level
1	Principles of Statics	21	26
2	Rectilinear Motion	24	22
3	Curvilinear Motion	20	20
4	Work, Energy, Impulse & Momentum	07	14

C. Phase III

As stated earlier in the discussion of Phase I, seeking active participation of students in the classroom for delivering most appropriate and meaningful feedback was a crucial part in this entire study. Students do not actively participate or become passive in the classroom despite encouragements and use of various teaching methods by the teachers. Abdullah et al., 2012, have stated the four significant factors that influence students' participation in the classroom [25]. These four factors are- i) Personality of a student ii) Influence of classmates or peers iii) Influence of teacher in the classroom and iv) Environmental factor. The first and most important factor which affects the students' participation lies in the personality of students. Typically those students who cannot focus during a lecture, fear of failing in front of classmates, fear of being criticized by teachers for giving incorrect answers and fear of not being able to speak correctly in the medium of instruction like English, are less participative in classrooms.

As stated by Hattie, 2012, the aim should always be to provide a feedback that was 'just in time', 'just for me', 'just for where I am in my learning process', 'just what I need to help me move forward' [4]. Hence to ensure active participation of students and to address the four aspects of effective feedback, any sole manual type of feedback intervention was ruled out for implementation in classrooms. There was a need to adopt an ICT tool which would allow easy, comfortable and active participation of learners, could provide an explicit provision to capture real time responses of the students and also provide a rapid summary of formative assessment in classrooms, thereby enabling the teacher to provide a meaningful & immediate feedback to students. Hence a ICT tool named MKCL(Maharashtra Knowledge Corporation Limited) SuperCampus, which provided all the necessary features was adopted for rigorous use in the classrooms. A few questions prepared in phase-I but related to the content delivered by the teacher were posed intermittently during a lecture on students' mobile using the MKCL SuperCampus tool. The software application collects and segregates the student responses and after each question, a real time statistics is provided to the teacher. This summary is useful in many ways as discussed in the following section. Additionally students are saved from distractions like Whatsapp alerts, Instagram alerts as their mobile is not connected to the internet. Gamification and excitement in the classroom is possible with the help of group competition feature of this tool.

3. Results and Discussion

The software application after collecting the student responses provides a real time summary to the teacher after each question. This summary includes details like the statement of the question posed, number of total responses, the multiple options provided, the correct option, segregation of the correct/incorrect responses and also the names of fastest five students who answered the questions correctly. The most important use of this summary is to find the level of understanding of the participating students. In a scenario, where majority students answer incorrectly, the teacher can address the gap in understanding by carrying out more meaningful interactions and providing appropriate feedback to the students. Fig. 5 to Fig. 7 show the snapshots of such question wise summary for a topic of Unit 1 of Engineering Mechanics. These snapshots are for a question posed for feedback at task level, however captured during implementation in three different classes. It can be noted that the incorrect responses are 17(out of 44), 14(out of 45) and 11(out of 40) respectively in Fig. 5, 6 and Fig.7. Thus the percentage of incorrectness, varying from 27.5% to 38.6%, is significant and it underlines the need to repeat the discussion to clarify the related concept.

Fig.8 and Fig.9 show a pair of snapshots of question wise analysis for a topic of Unit 2 of this course. These snapshots are for a question posed for feedback at process level. As can be noted in Fig. 8, the percentage of correctness is only 76.3% (29 out of 38). After giving feedback about the probable errors, the teacher repeated a similar question and its percentage of correctness improved to 95.1% (39 out of 41) as can be noted from Fig. 9. Similar rise in the number of correct responses, after giving feedback on first question, is noted across all 14 classes and the average percentage rise was observed from 65.7% to 83.9%.

An important factor that affects the active participation of students in the classroom, is the encouragement provided by a teacher. An experienced teacher can figure out active learners easily by their spontaneous participation and extend a word of appreciation for such learners. The projected statistics for every question, displays names of the fastest five students answering correctly and the final

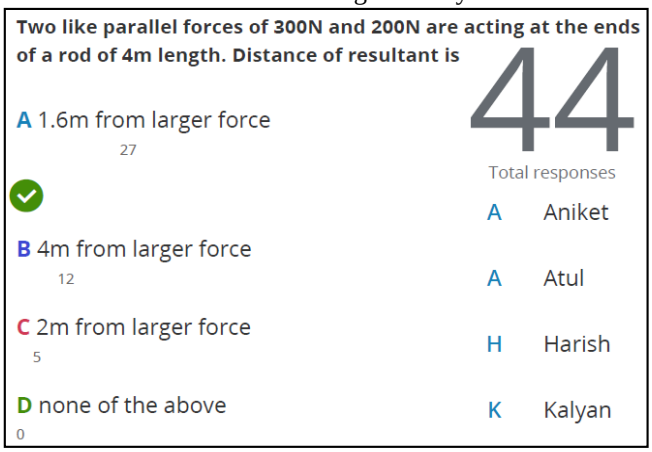

Fig. 5.Snapshot of student responses for question 27 of Unit 1 in Div.B

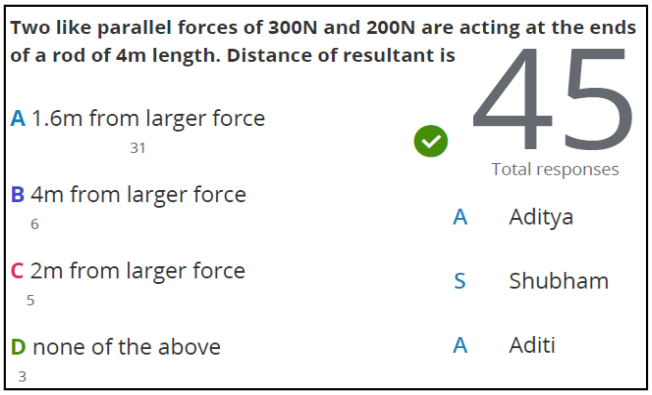

Fig. 6.Snapshot of student responses for question 27 of Unit 1 in Div.C

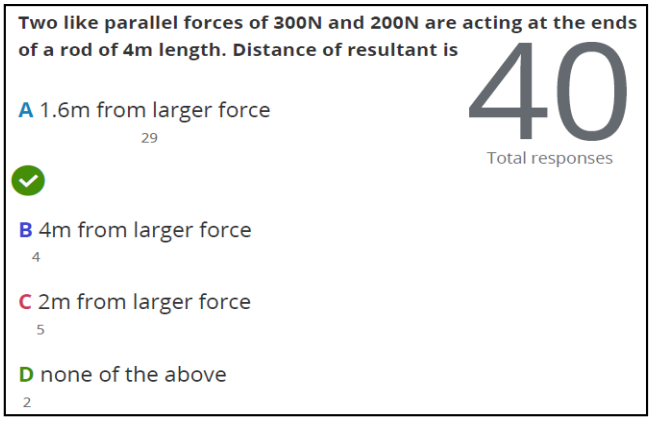

Fig. 7.Snapshot of student responses for question 27 of Unit 1 in Div.H

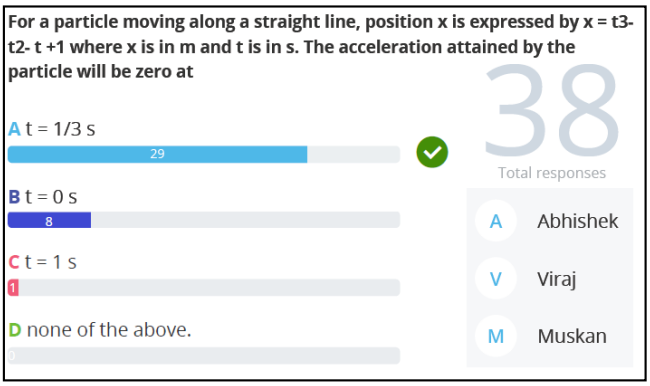

Fig. 8.Snapshot of student responses for question 14 of Unit 2 in Div.N

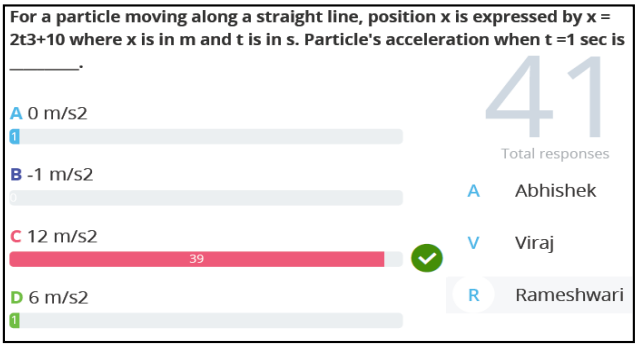

Fig. 9.Snapshot of student responses for question 18 of Unit 2 in Div.N

summary at the end of all questions displays five top scorers in that lecture. Display of names of top scorers opens a possibility for a teacher to appreciate an otherwise passive student and encourage him/her to participate more and improve further.

Individual student performance can also be tracked after every lecture to identify slow and advanced learners and the teacher can then discuss individually with them. Hence teachers can positively influence students though individual attention and appreciation.

Fig. 10 and Fig. 11 show the average percentage of correctness of all 14 classes for Unit-1 and Unit-2 questions. The average percentage of correctness for questions of Unit-1posed for feedback of both task as well as process levels was 61.54% and 64.96% respectively. The average percentage of correctness for questions of Unit-2 posed for feedback of both task as well as process levels was 64.52% and 59.64% respectively. Concepts related to question nos. 25 and 37 (indicated with red coloured arrow in Fig. 10) and question nos. 6, 21, 34, 36 and 38 (indicated with red coloured arrow in Fig. 11) need to be paid more attention since the average correctness across all divisions has dropped below 20%. Such insights are extremely useful to teachers for repeating certain concepts and correcting errors committed by students.

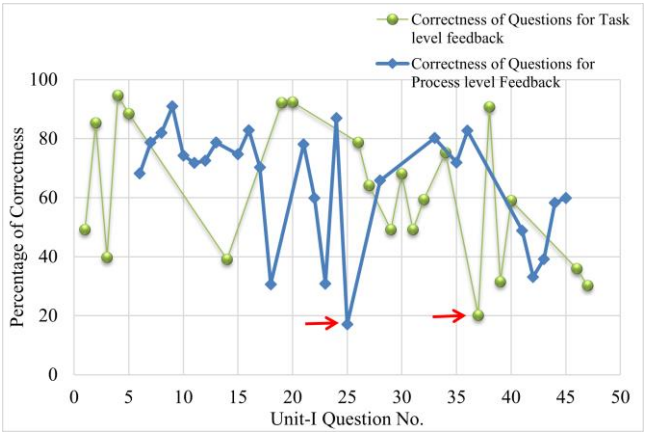

Fig. 10. Average percentage of correctness of all 14 classes for Unit-1.

In order to understand the impact of adopting the feedback intervention approach in teaching-learning of Engineering Mechanics course, a comparison of class wise passing percentage of online exam of the batch under consideration was made with the average passing percentage of online exam of the previous three academic years. In the previous three academic years, the feedback intervention approach was not incorporated while teaching the same subject.

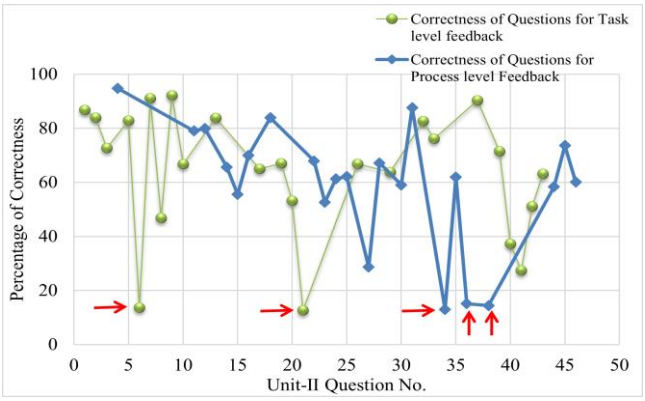

Fig. 11. Average percentage of correctness of all 14 classes for Unit-2.

For such a comparison to be independent of the other factors like intellectual ability of students of the four batches and teacher's competence, following aspects were ensured.

A sample class of students of one branch of Engineering i.e. Computer Engineering was chosen for comparison of students' intellectual capability. The merit score of the Engineering entrance exam was chosen as the parameter of comparison. Table 2 lists the comparison of the average and standard deviation of the entrance exam merit score, for the students of the batch under consideration and the batch of the previous academic year. Fig. 12 shows the normal probability distribution of entrance exam merit score for all the students of these two academic years. Since the average, standard deviation and the profile of the probability distribution of the entrance exam merit scores of the students of both the batches matches reasonably well, it can be assumed that the intellectual abilities of the students of both these batches is reasonably same. Although the intellectual capabilities (in terms of the

entrance exam merit score) of students might significantly differ within different branches of Engineering, it remains reasonably same in consecutive academic years.

Table 2 : Comparison of the Average and Deviation of Entrance Exam Merit Score for the Two Academic Years.

Academic Year	Average of Entrance Exam Merit Score	Standard Deviation of Entrance Exam Merit Score
2017-18 (Previous Batch)	98.61	25.06
2018-19 (Batch under consideration)	95.95	25.20

Due to several reasons, it was not possible to ensure same level of competence of the teachers involved in the present study and those involved in teaching of the course in previous three academic years. Rather, it was not even possible to retain the same teachers for teaching this particular course in consecutive academic years. Hence to overcome this limitation of having same level of teachers' competence and to nullify the effect of a probable variation in teachers' competence level to some extent, the comparison of class wise passing percentage of online exam of the batch under consideration was made not just with one previous batch but with the average of passing percentages of online exam of the previous three academic years.

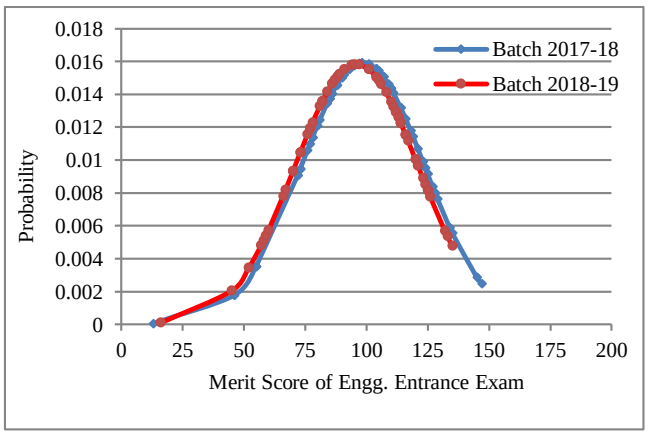

Fig. 12. Comparison of probability distribution of the entrance exam merit score for the two academic years of Computer Engg, students

The third parameter i.e. complexity of the exam question paper can also typically affect the performance comparison of the two batches. However in a typically university affiliated system, the complexity of the question paper does not change significantly in exams of consecutive years. This was confirmed by studying the question papers of the consecutive academic years. Finally, since level of complexity of the question paper cannot be controlled by the subject teacher in an university affiliated system, it has been assumed to be reasonably same in the consecutive academic years. Table 3 lists the class wise passing percentages of the batch under consideration and the average passing percentages of previous three consecutive academic years. A positive improvement in the passing percentage of the online exams is observed in 10 out of 14 classes with an average improvement of 2.82%. The highest improvement observed was 15.76% in Div. M. Inadequate and low quality of feedback, improper time management in class and overall low level of teaching quality are the probable reasons for a reduction in passing percentage of four classes.

Table 3: Comparison of Passing Percentages

Class / Division	Passing percentage of the batch under consideration	Average of Passing percentage of previous three consecutive years	Change in Passing Percentage
A	63.6	68.26	-4.66
B	88.1	87.49	0.61
C	91.8	88.95	2.85
D	92.1	89.99	2.11
E	81.4	79.09	2.31
F	87.1	87.77	-0.67
G	87.9	75.33	12.57
H	85.5	85.07	0.43
I	85	79.14	5.86
J	71.7	78.59	-6.89
K	83.3	73.39	9.91
L	80	85.05	-5.05
M	90.9	75.14	15.76
N	78.8	74.40	4.40
		Average	**2.82**

An intermediate survey was also conducted to find the extent to which the feedback intervention approach had helped students. A total of 402 students participated in this survey. The students were asked about how many questions they could attempt during classes for Unit 1 and Unit 2. Fig. 13 shows the number of questions of Unit-I and Unit-II typically attempted by students in classroom. There is definitely a lot of scope for encouraging the students to participate more actively in classrooms by ensuring their regularity in attending in classes.

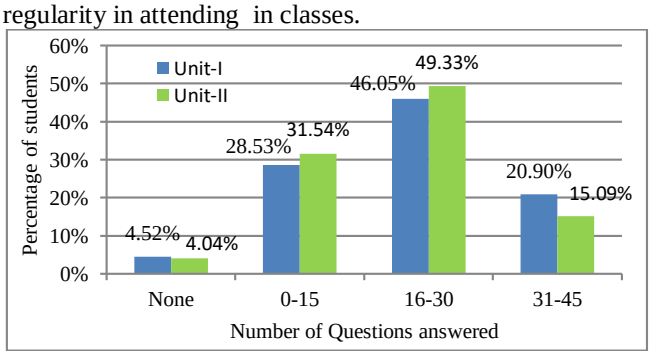

Fig. 13. Number of Questions attempted by students for Unit1 and 2

Fig. 14 shows that 208 out of 402 i.e. 51.74% survey respondents expressed that the use of the tool had helped them individually in all three mentioned aspects and the rest of the students admit that it has helped them in some way or the other. Thus mobile application of SuperCampus tool allowed a passive student to participate and make an attempt to answer the posed questions without any fear.

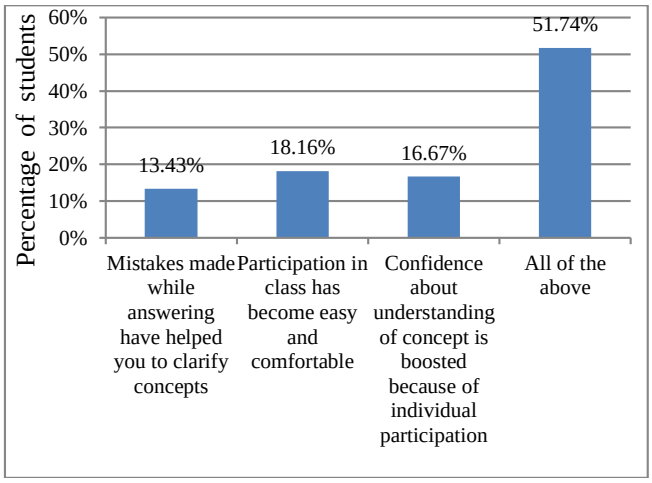

Fig. 14. Benefits derived by using the ICT tool.

Regarding whether such type of feedback intervention using an ICT tool be improved, continued and also extended for other fundamental engineering courses, 303 out of 402 i.e. 75% students have responded positively. 48 students have responded negatively whereas 53 students were uncertain about their opinion.

Conclusions

A simple and systematic procedure was implemented for feedback intervention in engineering classes using an ICT tool. Purposeful feedback by the teacher after every question posed in the classroom was provided

- to the students who needed it.
- at the stage of his/her learning process.
- with what was needed to direct him/her to move forward.
- at the time when it was needed.

Learning of wrong / incomplete information was therefore reduced due to the immediate feedback in classroom.

The use of an ICT tool allowed a passive student to participate without any fear, thereby addressing issues of passive personality traits and influence of peer classmates. It also effectively addressed in improving attention span of students, participation of students in the class and improving the conceptual understanding of students.

Based on both, the examination results and the survey outcomes, it can be concluded that the feedback intervention was successful in enhancing the learning outcomes of Engineering Mechanics and in providing a conducive learning environment. It can be extended in future to evaluate different levels of learning by incorporating questions that go beyond the level of testing information obtained by students during a lecture.

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