On Identifying Advanced, Average and Slow Learners: Case Study

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Abstract: Engineering education is dynamically changing its face by transforming from conventional passive learning to active learning across the globe. Active learning is a well-proven technique to enrich the understanding level of learners. However, the understanding, comprehension, and intellectual capabilities of every individual are different. It is highly important to identify these capabilities and provide the required knowledge feeding to intensify the curiosity of a learner in a specific course. Since the same course may not be understood by all the learners at the same depth, it is required to characterize the learning abilities of every learner. Thus, the learner community can be classified into advanced, average, and slow learners. In this paper, a strategy based on Bloom's Taxonomy (revised) is proposed for identifying advanced, average and slow learners in a course. For that, firstly, an online open-book test (OBT) covering all the levels of revised Bloom's Taxonomy is innovatively designed for each course. Secondly, the OBT is conducted as per schedule and question-wise, and thereby, Bloom's Taxonomy cognitive level-wise assessment is completed for all the courses. Thirdly, course-wise students are ranked from highest to lowest performance levels using statistical tools. Finally, using pre-decided thresholds, learners in a course are identified as advanced, average and slow. The application of this learner classification approach is demonstrated by considering the case of courses in the second, third, and final year of the Electrical Engineering program. The presented approach has substantial potential to be used for designing and planning course delivery to accommodate all types of learners.

Keywords: Advanced Learners, Average Learners, Bloom's Taxonomy, Electrical Engineering, Open-Book Test, Slow Learners.

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1. Introduction

"The illiterate of the 21st-century will not be those who cannot read and write, but those who cannot learn, unlearn and relearn [1]." The quote enlightens the change needed in the education system of the 21st-century. In India, this is going to happen with the implementation of the National Education Policy [2]. The conventional education system is based on reading, writing and arithmetic. This system ensures to impart the knowledge which enables the students to succeed in the examinations. However, the aim of education should not be to pass the examination but to acquire skills that can help the graduates to acquire lifelong learning skills. Apart from this, the 21st-century demands several other skills due to technological developments [3]. The graduate without these skills cannot contribute to the progress of the nation and mankind. The framework for 21st-century learning skills focuses on the 'Seven-Cs', namely creativity and innovation, collaboration, cross-cultural understanding, critical thinking, communication, computing technology, and career learning [3, 4]. Undoubtedly, all these skills can be transferred to students through academic courses. As a result, real-time, pressing societal, and other complex problems can be solved. On the other hand, if graduates are not empowered with these skills a gap will be created in the problem-solving process. The 21st-century problems relating to the United Nation's Sustainable Development Goals [5] are complex compared to an earlier era. Thus, the students must learn to work with and listen to a variety of points of view.

When the expectations of the students in education have changed, naturally the teachers have to align their teaching styles to fulfill these modern requirements. The teaching-learning practices should be more and more activity-based. The teachers should facilitate student learning and creativity so that all students succeed in a global society. Teachers are also expected to make full use of the modern tools of teaching to improve student's engagement and achievement [6]. For example, in [7], the application of ICT tools is suggested for electrical engineering courses before starting, while delivering, and after concluding the course. It is also possible to classify students depending upon their ability to grasp the knowledge. For any teacher, to understand this classification for his or her set of students is very important to plan the teaching efforts. This helps to bring all the students on a common platform for the course being taught. Another advantage is that some more activities can be planned for the course to make use of the abilities of advanced learners whose outcome may be similar to the research outcome. From a student's point of view, the classification of learners helps in the improvement of an individual and helps to succeed him or her in the course with

special efforts taken for learning. This is also having an advantage in terms of time investment in the course as more time can be invested for the students with lesser ability to grasp the course. In a nutshell, the classification of the students as advanced, average, and slow learners is a microscopic approach to understand the learning needs and also to identify the potential of every individual. This is different from the conventional generalized way of teaching without considering the difference in student's learning competencies.

There are many types of assessments to measure student's learning capabilities. However, the written examination is the most common approach used by any higher educational institution. Question is an element that is intertwined with the examination. Questions asked in the examination play an important role in testing the students' overall cognitive levels. Effective style of questioning, described by Swart [6], is highly useful in ensuring the attainment of the desired learning outcomes in students. In [6], a strategy for designing effective questions (higherorder questions and lower-order questions) using Bloom's Taxonomy [8, 9] to ascertain the assessment of problemsolving and critical-thinking skills of students is suggested. Further, in [10], the concept of [6] is extended by implementing a combined strategy based on a voting algorithm that combines three machine learning classifiers. However, in both [6] and [10], the study is limited to only designing question papers and the types of learners are not identified based on assessment. Studies on enhancing skills of slow learners are reported in [11], in which quantitative analysis is carried out to reveal that, the academic interventions are highly effective in enhancing the developmental skills of slow learners. Although the slow learner's skill enhancement problem is discussed in [11], the presented method does not identify slow learners. In this, a random group of students is selected for the study. Kaur *et al.* [12] suggested a classification-based algorithm employing a predictive data mining model to identify and display slow learners. Real-world data of the slow learners from a high school is taken for the same. But, the applicability of the same to the undergraduates and graduates is less effective. Recently, a new type of classification, i.e. instructor-dependent and instructorindependent, of the graduate and undergraduate students of Electrical Engineering is presented in [13]. In this, the instructor-dependent students are categorized as a slow type of learners and instructor-independent students are grouped and advanced learners. In another study, a proposal for identifying slow learners is presented [14]. Nevertheless, there is no study, so far, to identify or classify advanced, average, and slow learners separately. This paper aims to propose an approach for determining course-wise groups of advanced, average, and slow learners based on the examination (an online open-book test), having questions designed using the revised Bloom's taxonomy cognitive levels. First of all, an examination question paper pattern is decided unanimously for all the courses of the Electrical Engineering program. Then, the questions are framed as per the cognitive levels of revised Bloom's Taxonomy. The

examination was conducted for all the students and the question-wise assessment of the answer sheets submitted by students is carried out for all the courses. Using statistical tools, test performance levels of the students are found out and then learners are categorized as advanced, average, and slow learners using pre-decided thresholds. This approach helped to identify an individual's learning requirements in different courses of the semester.

The rest of the paper is organized as follows. In Section 2, the brief background of the study is explained. Section 3 presents the experimental design of the study. Results and discussions are presented in Section 4 followed by a conclusion in Section 5.

2. Brief Background

The purpose of this section is to provide brief information on Bloom's Taxonomy, students and the curriculum, and open-book test. Although Bloom's Taxonomy and revised Bloom's Taxonomy are well-known and well-discussed in the literature, it is given for brevity. Whereas, the details about students, courses, and curriculum are given and described to understand the diversity in it. Finally, an option of the online open-book test is justified in short.

A. Review of Bloom's Taxonomy

In 1956, Benjamin Bloom presented six-level cognitive processes, namely knowledge, comprehension, application, analysis, synthesis, and evaluation, and these are widely accepted and used in numerous frameworks ever since [8]. These cognitive processes are arranged from the simplest to the most complex, i.e. from recalling knowledge to making judgments about an idea. An updated version of Bloom's Taxonomy appeared in 2001, considering comprehensive factors impacting teaching and learning [9].

Table 1. Four categories of knowledge dimension of revised Bloom's Taxonomy

Categories	Description
Factual	Includes isolated bits of information, such as vocabulary, definitions and knowledge about specific details.
Conceptual	Consists of systems of information, such as classifications and categorization.
Procedural	Includes algorithms, heuristics, or rules of thumb, techniques, and methods as well as knowledge about when to use these procedures.
Metacognitive	Refers to the knowledge of thinking processes and information about how to manipulate these processes effectively.

This revised taxonomy attempts to correct some of the problems associated with the original taxonomy. Its knowledge dimension has four categories and the cognitive process dimension has six skills. These are briefly described in Tables 1 and 2 respectively.

Table 2. Six skills of the cognitive process dimension of revised Bloom's Taxonomy

Skills	Description
Remembering	Consists of recognizing and recalling relevant information.

Understanding	The ability to make your own meaning from the educational material.
Applying	Using a learned procedure either in a familiar or new situation.
Analyzing	Consists of breaking knowledge down into its parts and thinking about how the parts relate to its overall structure.
Evaluating	Includes checking and critiquing.
Creating	Involves putting things together to make something new.

B. Overview of the Students and Curriculum

In this, a case of students from the Electrical Engineering program of the K. K. Wagh Institute of Engineering Education and Research is considered. The institute is affiliated with Savitribai Phule Pune University (formerly Pune University), Pune. This experiment of identifying advanced, average, and slow learners is done with the second-year (SE), third-year (TE), and fourth (final) year (BE) engineering students. Due to COVID-19 the firstyear (FE) engineering admission procedure has not started. Hence, the first year (FE) engineering students are not included. The total number of students is 406, including 136 students from BE, 155 students from TE, and 115 from SE. Nashik is located on the northern side of Maharashtra and the student intake is from all over Maharashtra. This includes students with urban and rural backgrounds, English and vernacular mediums, the higher secondary school completed, and professional Diploma completed, etc.

As an affiliated institute, the curriculum is revised after every four years in a progressive way. The last revision of the curriculum happened in 2019 and the last-to-last in 2015. That means, TE and BE students are having the 2015 pattern of curriculum, and SE students are having a 2019 pattern of the curriculum. Further, this experiment was conducted from August 2020 to October 2020, i.e. in the odd semester of the academic year 2020-21. For each course, course prerequisites, objectives, outcomes, contents, and text and reference books are prescribed by the Board of Studies of University. Each course has six units. The curriculums of SE, TE, and BE are available online [15]. Typically, the course has mathematical, analytical, and theoretical contents. The mapping of the courses in the odd semester of the Savitribai Phule Pune University of Electrical Engineering program to this content is given in Table 3. In this mapping, 3 indicates the highest level of mapping and 1 indicates the lowest level of mapping. This mapping is given just for understanding the nature of the curriculum.

C. Brief about Open-Book Test

Conventionally, in the closed-book test, students are not allowed to carry or use any study material. On the contrary, in an open-book test (OBT) students can refer to study material during the test. Very recently, studies have been published on conducting online open-book examinations [16] and its impact on learning [17]. Due to COVID-19, all over the world universities and colleges are adopting an online open-book test or examination pattern to maintain social/physical distancing. Even though the studies

presented in [16] and [17] are restricted to medical students, the results presented are promising. As mentioned in [17], students appearing for open-book tests prepare very proactively by understanding the content and its application for problem-solving, thus encouraging deep learning. It is also observed that the students feel less anxious about the examination, which is reflected in significantly higher test scores [16]. Considering these benefits, it was decided to go for an online open-book test on the first two units of the course. Only the first two units are considered because on average two units were completed by all the course-coordinators (teachers) by the end of September 2020. The OBT schedule was displayed a week before. Considering 100 marks and 3 hours for all the six units as per the regular university examination structure, an online OBT was conducted for 30 marks and a 1-hour duration for all the courses. After the OBT, 30 minutes were given for uploading the answer-sheets via Google form. The structure of the OBT is discussed in Section 3-A.

Table 3. Mapping of the courses, M-Mathematical content, Aanalytical content, T-Theoretical content

S.N.	Name of the course	M	A	T
	Second Year (SE) 2019 Pattern			
1	Power Generation Technologies (PGT)	2	2	3
2	Engineering Mathematics III (M3)	3	2	1
3	Material Science (MS)	1	2	3
4	Analog and Digital Electronics (ADE)	2	3	2
5	Electrical Measurements and Instrumentation (EMI)	2	2	3
	Third Year (TE) 2015 Pattern			
1	Industrial Technology and Management (ITM)	1	1	3
2	Advance Microcontroller and its Applications (AMCA)	1	3	2
3	Electrical Machines II (EMCII)	2	2	3
4	Power Electronics (PE)	2	3	3
5	Electrical Installation Maintenance and Testing (EIMT)	1	1	3
	Final Year (BE) 2015 Pattern			
1	Power System Operation and Control (PSOC)	2	3	1
2	PLC and SCADA Applications (PLC)	1	3	2
3	Power Quality (PQ)	2	3	2
4	Electric and Hybrid Vehicles (EHV)	1	2	2
5	Control System II (CSII)	3	3	1

3. Design of the Experiment

In this section, the complete design of the experiment to identify advanced, average, and slow learners is demonstrated. First of all, the uniform structure of the question paper is defined for the open-book test for all the courses using the revised Bloom's Taxonomy approach. Also, the threshold criterion is decided for a particular type of learner. Then the OBT was conducted as per the schedule and answer-sheets are collected by Google form. Latter, the question-wise assessment is carried by respective course-coordinators. Finally, based on the decided threshold

criteria, the students are grouped as advanced, average, and slow learners for each course.

A. Structure of OBT

Overall marking scheme and duration for OBT are already discussed and justified in Section 2-C. In this, the question-wise structure is discussed. The structure of the OBT is decided by considering course content (i.e. first two units of the curriculum), course outcomes, faculty (course-coordinators) inputs, and revised Bloom's taxonomy skills. It is illustrated in Fig. 1. Typically course outcomes are defined for each unit in the course and those are considered while deciding the structure. If not, the course outcomes mapping with the respective Units are taken into account. To include all the types of questions, an appropriate mixture of objective and subjective type questions is done. These questions are then framed as per the six skills of the cognitive process dimension of revised Bloom's Taxonomy as mentioned in Table 4. As the partial teaching is completed for all the courses, the maximum weightage is given to the middle two levels, i.e. applying and analyzing and nearly the same weightage is given to the first two (remembering and understanding) and last two (evaluating and creating) levels. The verbs required to frame the questions in a particular level are selected from [9]. In this way, the question papers are structured.
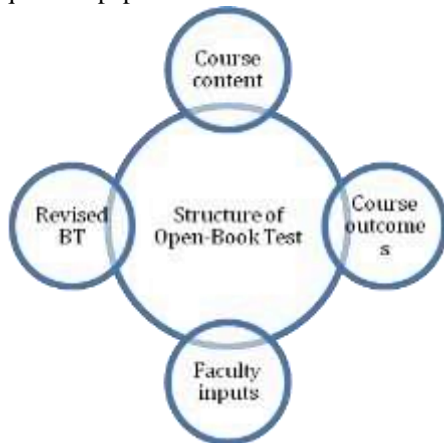

Fig. 1 Process followed for defining the structure of the open-book test.

Table 4. The question paper structure of an open-book test

Q.N.	Type of Question	Revised BT Levels	Assigned Marks	%
1	Multiple Choice Type	Remembering Understanding	6	20.0
2	Subjective Type	Applying Analyzing	16	53.3
3	Subjective Type	Evaluating Creating	8	26.6

B. Assessment of OBT

The question-wise assessment of the answer-sheets is carried out by an individual course-coordinator for his/her course. Since it is an online OBT, it is assumed that all the students have solved it without copying or by using the recommended reference or text materials (Assumption 1). On their own means, from their own study or reference material and not from the answers-book of other students.

Also, it is assumed that, if two faculties are teaching the same course to two different classes (divisions), they have discussed together and finalized the grading for both the classes to have uniformity in grading for the same course (Assumption 2).

C. Classification of Learners

For the classification of learners, the following concepts from statistics and probability [19] are used. 1) *Median*: Median is the 'middle value' of the data set which separates the data into two different sets. 2) *Standard Deviation*: It gives an idea about the range of spread. This also helps to understand whether, in any course, all the students are performing almost the same or different. If the standard deviation comes very near to the average performance, it can be concluded that all the student's performance is almost the same. The standard deviation (σ) is the positive square root of the variance (σ^2) and is given by

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{1}$$

where x_i is the ith sample of the data, n is the number of samples and $\bar{x}$ is the arithmetic mean of the data expressed as

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n}x_i \tag{2}$$

3) *Normal Distribution*: It is also called the bellshaped curve. It is written as

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}}e^{-\frac{(x_i-\bar{x})^2}{2\sigma^2}} \tag{3}$$

For the normal distribution (Bell Curve), the mean and median are the same. The bell curve is a very popular technique in corporate companies to categorize the employees into high, average, and low performers [19]. The aim of the study performed in this paper is analogous to it. Therefore, these concepts are used.

Let us take an example of the BE course Control System II (refer to Table 3) as a case study. For uniformity, the marks for each question are converted to a scale of 10. The median of the marks obtained for these three questions is calculated separately as 9, 9 and 0. Standard deviations for questions 1, 2, and 3 are obtained as 2.53, 2.62, and 2.28 respectively. Using median and standard deviations estimated for each question, the normal distribution function of each question is calculated. Finally, normal distributions of the three questions are summed and again median, standard deviation, and normal distribution are calculated for the summation. This final normal distribution is arranged from the highest value to the lowest value (1 to 0). This complete

analysis is done using Microsoft Excel (2013). The same analysis is then repeated for all the courses.

After this analysis, the challenging task was to decide the thresholds for segregating the advanced, average, and slow learners. For this, the reference from University Examination is taken and is given as in Table 5.

Table 5. Thresholds for classification of learners

Type of Learner	Threshold for classification
Advanced Learners	$0.7 < f(x) < 1$
Average Learners	$0.3 < f(x) < 0.7$
Slow Learners	$0 < f(x) < 0.3$

In University examination, 70 % is considered as the distinction score hence students with the normal distribution in the range of 0.7 and 1 are grouped as advanced learners. Although below 40 %, students are considered as failed, here a lower limit is set to 30 % (considering 10 % grace marks). Hence, students with normal distribution in the range of 0 and 0.3 are grouped as slow learners. And, remaining students with normal distribution in the range of 0.3 and 0.7 are termed as average learners.

4. Results and Discussions

Using the procedure explained in Section 3-C, analysis is carried out class-wise (separately for SE, TE and BE) to determine advanced, average, and slow learners. First, it is done for SE as given in Fig. 2. From Fig. 2, it can be seen that in the course Power Generation Technologies (PGT) there are 31 (27 %), 56 (49 %) and 28 (28 %) advanced, average and slow learners. And so is the case with other courses (for full forms of the courses, refer to Table 3). Percentage values in the bracket are calculated with reference to the total number of students, 115. Similarly, the analysis is completed for the TE and BE as depicted in Figs. 3 and 4 respectively. Analysis of the course Power Electronics (PE) was not available at the time of analysis, hence it is not included in Fig. 3. Rest all the courses are included.

From Fig. 2, it can be noticed that the mean values of advanced, average and slow learners are 24 %, 52 % and 24 % respectively. Further, it is observed that the number of advanced learners is nearly in the same range for PGT, MS, ADE and EMI. Whereas for M3 it is reduced by 50 %. On the contrary, the number of average learners in M3 is around 40 % more than the average learners in the other four courses. And, the number of slow learners in EMI is more compared to all other courses. This shows that more attention is required to focus on M3 and EMI.

From Fig. 3, it can be found that the mean values of advanced, average and slow learners are 24 %, 44 % and 32 % respectively. Here, the percentage of average learners is decreased and the percentage of slow learners is increased compared to SE. And the same case, like that of M3 in SE, is observed here for EIMT, necessitating more attention.
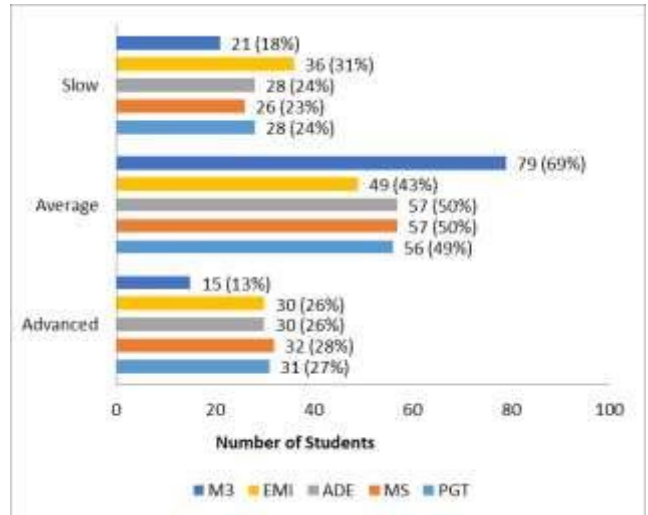

Fig. 2 Course-wise classification of learners in Second Year (SE) for a group of 115 students
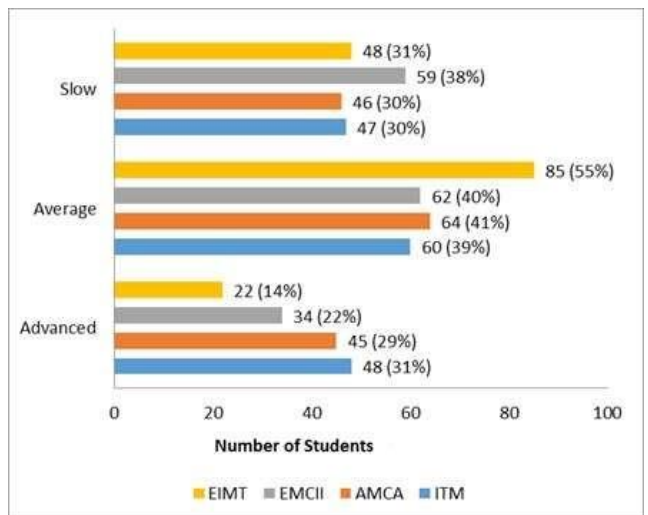

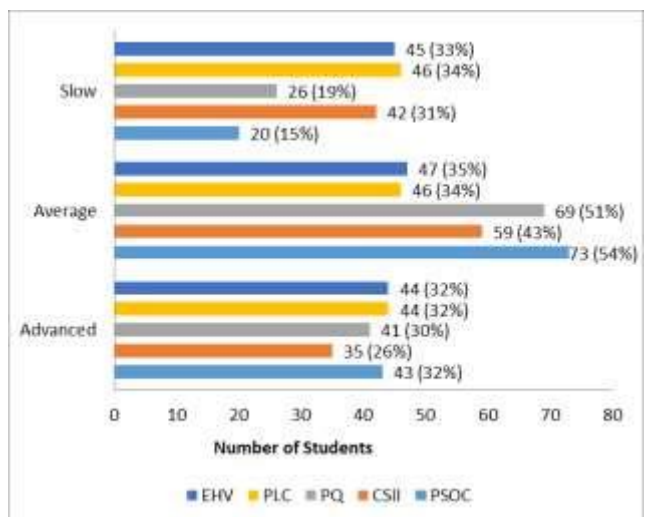Fig.3 Course-wise classification of learners in Third Year (TE) for a group of 155 students

Fig.4 Course-wise classification of learners in Final Year (BE) for a group of 136 students

From Fig. 4, it can be noted that the mean values of advanced, average and slow learners are 30 %, 43 % and 26

% respectively. Even if the percentage of slow learners is less than TE, the number of learners is more for CSII, PLC, and EHV than PSOC and PQ. Moreover, the number of learners in all the categories is much more non-uniform than SE and TE.

It is expected that, with the systematic and consistent efforts from the course-coordinators, the number of advanced learners should increase and the number of slow learners should decrease from SE to BE for the same group of students. But this requires steady efforts and experiments for three consecutive academic years to check the improvements.

One interesting fact is observed in this analysis, i.e. a student-wise summary is obtained as demonstrated in Fig. 5. This is a sample case of 'Student 1', where he is found to be an advanced learner in ADE, an average learner in MS and EMI and a slow learner in PGT. It is worth noting that, this summary is not prepared for sharing with students, but it is prepared only for the course and class coordinators to understand individual student learning levels and take corrective actions.
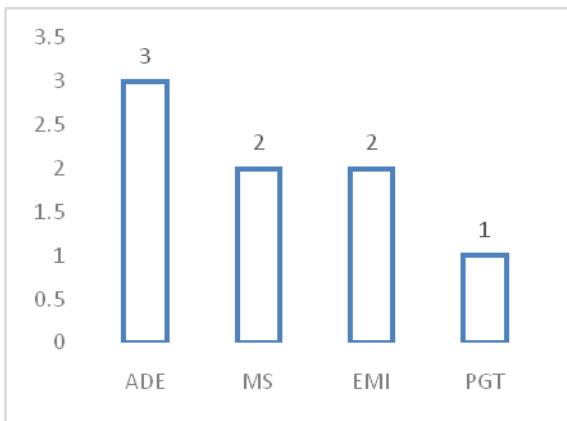

Fig. 5 Learning levels of 'Student 1' in all the courses, 3-Advanced, 2-Average, and 1-Slow

Another intriguing aspect of this study helped to identify class-wise advanced or average or slow learners in 1course, 2-courses, 3-courses, and so on. These are plotted in Figs. 6, 7, and 8 for SE, TE and BE respectively. Fig. 6 indicates the number of students, out of 115, for each bar. For example, 34 students are found to be advanced learners in 1-course, 38 students are found advanced learners in 2-courses and likewise, 8, 1 and 0 students are found advanced learners in 3, 4 and 5 courses respectively. Similar is the case with average and slow learners in the same class SE (Fig. 6). In the same way, the analysis is done for TE as given in Fig. 7, where the total number of students is 155 and for BE as represented in Fig. 8 with total number of students as 136. This analysis is very useful to identify the students which are extremely weak in almost all the courses and separate remedial sessions can be arranged for these students. On the other hand, the potential of students as advanced or average learners in almost all the courses can be utilized to carry out the research-based and project-based activities enhancing their capabilities further. It is believed that, if this type of

analysis is done at the beginning of the semester, it can be immensely useful for the planning and execution of the rest of the semester more effectively and productively. Slow learners can be transformed into average learners, average learners can be transformed into advanced learners and advanced learners can be groomed further to enhance their employability and entrepreneurial skills. Analyses in Figs. 2 to 5 are useful to the coursecoordinators and analyses in Figs. 5 to 8 are useful to the class-coordinators. On taking efforts, after the identification of learners for the rest of the semester, one more exercise is required to be conducted to see the improvement in individual student, course and class.
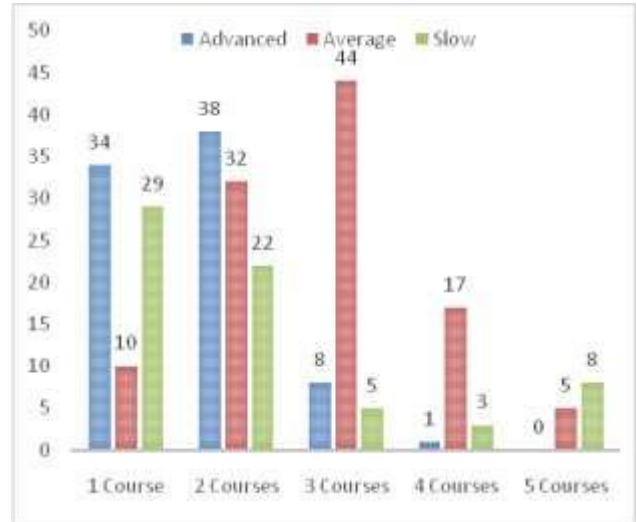

Fig. 6 Course-wise advanced, average and slow learners in SE out of 115 students

Fig. 7 Course-wise advanced, average and slow learners in TE out of 155 students

Even though the study is carried out, very extensively for three classes with 406 students, it has a limitation that the thresholds (Table 5) for identifying advanced, average and slow learners are taken as a uniform for all the courses. In fact, they can be taken differently for different courses depending upon the type of content in it. Another limitation is that test (exam) is carried out in online mode due to COVID-19 and for that Assumption 1 is stated in Section 4-

B. More promising results can be obtained if the test is conducted in off-line mode.
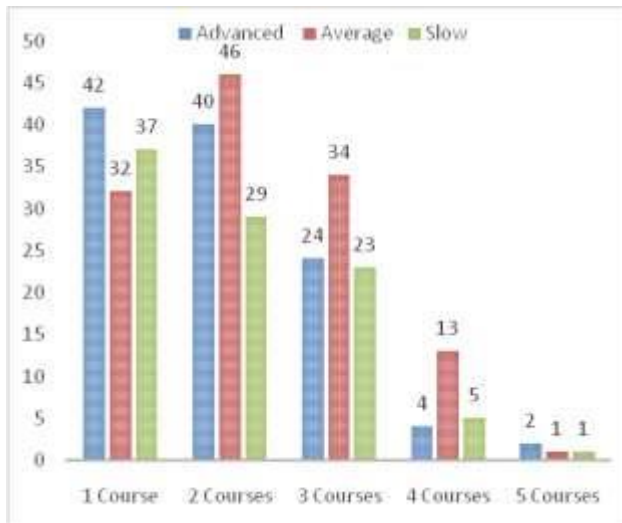

Fig. 8 Course-wise advanced, average and slow learners in BE out of 136 students

Although there are limitations the study provides an initial comprehensive analysis of different types of learners. Multiple experiments, of this type, on the same group of students, will really help to decide a strategic plan for academic improvement and thereby reaching the program educational objectives set by the department and program outcomes given by the National Board of the Accreditation.

5. Conclusions

In this paper, a systematic methodology is proposed to find the advanced, average, and slow learners in a class based on the revised Bloom's Taxonomy levels. The suggested method is demonstrated with the students in the second, third, and final year for 4 to 5 courses. The three main advantages of the study are listed below.

1)   In each course, advanced, average, and slow learners can be recognized separately.

2)   An individual student with different learning rates can be marked.

3)   Number of students either advanced or average or slow learners in 1-course, 2-courses, 3-courses, etc. can be identified.

Based on this classification, the academic improvement plan can be developed and the all-round growth of the undergraduates and the department can be achieved. Further, the limitations of the study are listed which can be overcome in future studies. Apart from this, the use of intelligent techniques, like machine learning, i.e. a classification technique can be used to increase the efficiency of the method.

Acknowledgement

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