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A Framework for Computerized Adaptive Assessment based on Trajectory Driven Pedagogy Implemented in an Engineering Course

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Abstract: Engineering education needs to be flexible with the changing technology, and it must blend traditional and new teaching pedagogy for the overall knowledge creation in the students. A survey of prevalent experiential learning methods has shown tremendous potential to improve engineering students' learning. However, existing experiential learning methods are hard to integrate with current teaching-learning process at Amity University, Uttar Pradesh, Lucknow Campus, India. A pilot study conducted during Power plant Instrumentation taught in the seventh semester of the Electrical and Electronics undergraduate program balances the current teaching method with the proposed Trajectory -driven pedagogy as an alternative teaching pedagogy. A trajectory driven computerized adaptive assessment procedure for teaching has been proposed in this paper. The system follows a trajectory of courses to generate the subsequent questions from the vast database of questions. A sequence of questions is guided by Concept Map which represents the questions from three courses in a hierarchical manner. Analysis of students' assessments shows that the proposed methodology could is accurate for quantitative measurement of the course learning outcomes in a summative assessment.

Keywords: Adaptive assessment techniques, Experiential Learning, Game-based learning, Problem-based learning, Project-based learning, Trajectory based assessments.

1. Introduction

Engineering education needs to adapt the intricacies of rapid technological changes. But it brings a significant challenge for engineering educators to incorporate these adjustments along with the other constraints of curriculum. Experiential learning was a significant way of effectively encouraging, engaging, and motivating the learner to gain deeper, significant, and meaningful knowledge [1-2].

Engineering education at the university must enable students to transfer (apply) their knowledge to solve an engineering problem. Understanding the underlying cognitive processes is crucial while solving engineering design problems. Cognitive development means developing a significant understanding of problem-solving skills and attaining expertise in solving numerical problems. These factors stimulate early foundations of learning, problem-solving, reasoning, and regulatory processes in the development of critical thinking [3]. Engineering education ought to be adaptive to the changing technology, and it must merge traditional and new pedagogical techniques for overall knowledge creation in students. Research has shown evidential improvement in students' learning by including experiential learning-based teaching methods [3].

The proposed pedagogy blends traditional teaching methods and experiential learning-based for the effective delivery of engineering courses for an undergraduate engineering student. This work introduces 'Trajectory Driven' pedagogy along with trajectory implementation of assessment method for Department of Electrical and Electronics Engineering at Amity University, Uttar Pradesh, Lucknow Campus, India.

Although experiential learning-based methods have improved the students' learning, in current scenario, it is not easy to bring about many changes at Amity University. A review of Experiential learning-based teaching methods identified that such methods require specialized course instructors, additional infrastructure, and curricular planning for implementation of assessment methods. Trajectory-driven pedagogy does not require any infrastructure-based change for implementation and its content delivery method can be included within the

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current teaching framework to enhance learning at the undergraduate level of engineering education.

Trajectory-driven assessment is helpful for evaluating the students' knowledge of fundamental topics studied in the lower semester and their role in learning the topics of courses that they study in the higher semesters. For this work, a trajectory of course Power Plant Instrumentation along with its two prerequisite courses, as mentioned in the course structure, has been used.

This activity was not mandatory, and students voluntarily participated in the test group. The authority granted permission to study at the University. The assessment of volunteers was conducted as a formative assessment, and scores obtained by students would not be included in their final semester grades.

The proposed framework of the Trajectory based computerized Adaptive assessment method improves the efficiency and effectiveness of the assessment process, as shown in the results and discussion.

Results show that adaptive assessment can measure students' performance in associative learning, which says, if they are not well acquainted with the prerequisite knowledge, they cannot score in the overall assessment.

The organization of the remaining part of the paper is as follows: Section 2 discusses the literature review. Section 3 discusses the Trajectory-based pedagogy for effective content delivery and evaluation of students' knowledge. Section 4 presents a case study for the development of computerized adaptive assessment. Section 5 discusses the results and Section 6 concludes the paper following the future work.

2. Literature Review

This section discusses the development of the experiential learning-based methods prevalent in engineering education based on prominent theories. Based on these theories, a few pedagogies like Project-based learning, Problem-based learning, and game-based learning are in practice. Educators have prominently employed these methods in various courses; this section explains the essential aspects of these methods and the assessment methods adopted for these teaching pedagogies. The review suggests that implementing such methodologies has challenges and limitations.

2.1 Prevalent pedagogies based on experiential learning theory implemented for engineering students

Experiential learning has gained much momentum in various engineering courses in recent years. Various experiential learning models are employed to support students' cognitive development. Experiential learning theory provides a holistic, integrative learning perspective [4]. Lewin, Dewey, Piaget, and Kolbe have significantly contributed to redefine the learning models based on ELT [5].

Lewin's method emphasized two aspects of learning: firstly, direct personal experience provides meaning to abstract concepts. If these experiences can be shared publicly, it validates the idea generated during learning. Secondly, feedback is essential to provide valid information and prevent deviation from desired goals.

Dewey's method focuses on purpose formation through observation, knowledge, and judgment. He emphasized that learning is a dialectic process to integrate experiences and concepts through observation and action. Experiential learning provides the freedom to interact with the learning content. A teacher ensures the transfer of subject matter knowledge to the students. So, the teacher must know students' abilities, needs, and past experiences.

Piaget's Method: In this theory, Piaget stated that learning is the process of continuous interaction between the individual and the environment. According to him, learning depends mainly on the accommodation of concepts and assimilation of events and creating a balance between these two aspects. The process of cognitive growth must occur from concrete learning to abstract learning. The concrete learning style corresponds to learning senses and developing goal-oriented behavior. Abstract learning will depend on the symbolic process of representational logic by developing reflective and abstract power.

Kolbe's Method: While adopting the experiential learning-based pedagogy, Kolbe's experiential learning is influential as it describes the process into discrete steps. Thus, making it simple to understand and evaluate the whole process at each step [4-6]. Kolb's cycle of experiential learning has four steps:

(1) Concrete Experience: It explains the phenomenon of being involved in some experience.

(2) Reflective Observation: This explains the observation-based experience or watching others.

(3) Abstract conceptualization: Based on logical thinking and rational evaluation.

(4) Active experimentation: Using theories to solve problems and make decisions based on these theories.

2.2 Prevalent pedagogies based on experiential learning theory implemented for engineering students and their assessment methods

In engineering education, it is a huge responsibility to select teaching methods that provide a conducive environment for improved performance based on the knowledge of the courses of the subsequent semesters [7]. Various pedagogies have evolved for an interactive and efficient atmosphere in engineering classes, like Project-based learning, problem-based learning, cooperative learning, and game-based learning.

2.2.1 Project-Based Learning:

In this method, learning objectives are defined with the help of an instructor or teacher to provide directions for work to find a

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solution, acquiring knowledge and skills during the work through continuous and interactive experiences [8-9]. Initially, students learn to design with incomplete information and address the system requirement based on that information [10], and gradually they complete the design by experimentation. They develop teamwork spirit and organizational behavior during the implementation of micro and macro tasks. They also become aware of interdisciplinary tasks and learn to resolve relevant issues [11-12].

Assessment Methods in Project-based Learning: Assessment is continuous evaluation, and it proceeds along with the progress of the Project. It can be in the form of quizzes, presentations, reports, approaches toward the solution arising during the implementation of the project and open-ended assessment strategy [13]. Assessment evaluates a student's ability to make meaningful decisions on learning in the form of comprehensive and competency-based assessments [14] [15].

2.2.2 Problem-Based Learning:

It develops an ability to identify the Problem and set parameters for a solution making it a self-directed learning experience [16]. An ill-structured problem is selected as it garners more effort from the learner, invoking critical thinking. It requires the ability to integrate information to resolve a particular problem and the degree of dynamicity and relational complexity leads to a deeper interpretation of related concepts [17-18].

Assessment Methods in Problem-based Learning: Conduct of self and peer assessments after each Problem and at the end of the curricula unit demonstrates the student's ability to contextual factors of problem-solving through analysis [10] [20]. Various factors are time spent on reaching the solution, number of relations processed, number of interrelationships, and number of steps executed in finding a solution [21].

Through self-assessment, the student evaluates their ability to apply knowledge in problem-solving. Peer assessment between group members provides insight into individual’s teamwork and organizing capabilities. When self-assessment and peer assessment mismatch, the teacher's assessment relies on students' performance [22].

2.2.3 Game-Based Learning:

Games can generate a high level of engagement in terms of cognition, rich contextual knowledge, and interaction [23]. They provide continuous feedback as rewards and success which build a reinforcement schedule for an excellent response rate. Games designed for GBL must be relatively easy and challenging. They must generate an optimal amount of struggle throughout the game's tenure. Games mechanics inculcate adaptivity, graceful failure, and motivation that allows a deeper engagement with content where learning objectives are mapped with instructional strategies like the evidence-based design to induce learning and improve comprehension [24]. Games, designed as a critical heuristic, progressively increase the complexity by putting up challenges [25].

In Game-based learning, learners score points while playing a game that provides immediate feedback for a specific area of difficulty such as—(1) target acquired, (2) obstacles overcome or (3) time spent on completing a task [26]. Scores are calculated during the process of problem in the game as embedded assessment. It is embedded so that it does not interrupt the game while playing. It is in log files or information trails weighing the students' performance during the play. Apart from that, external assessment such as briefing Interviews, tests, essays, knowledge maps, and causal diagrams evaluates students' performance. Information trials are assessment methodologies to collect user-generated action data [27].

2.3 Challenges in the implementation of Experiential Learning Methods

Experiential learning-based methods are helpful, but their implementation requires a lot of time and effort at the level of the institute, teachers, and students. It would need re-designing of the course module and a new approach for the assessment process. These methods cannot be implemented in their current form in our university due to the need for training to design experiential learning-based specific modules, industry-based collaborations, and required infrastructure. The role of institutions is significant in implementing these systems to provide the necessary flexibility for completing modules [28]. Our universities run on a tight schedule and need more space for flexibility in assessment and completion of the modules that fulfill the requirement of implementing any project or problem. Due to these limitations, it is impossible to implement the existing experiential learning-based methods at Amity University. Significant limitations as reported by these studies [29-31] are summarized further.

2.3.1 Active Experimentation:

In experiential learning-based case studies, design is part of active experimentation which involves abstract conceptualization and reflective observation. Students understand the technology through the implementation of these projects. There are various challenges faced by students in this area, such as:

Lack of macro-level skills: Designing the Project is a complex and multi-level process, but it is necessary to enhance the student's knowledge and expertise in it and its technologies. It requires a significant level of dedication to complete the process. A high indulgence in one project may deviate students to other contemporary technique or topic. Also, in project-based and problem-based learning, students are allotted a particular design aspect that contributes to the project's development or solving the problem as a group member. Therefore, they

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mainly enhance their knowledge by focusing on the task allotted to them. They may need to create a different knack for the design at the macro level.

Less emphasis on theoretical concepts: Students concentrate on designing, simulating, and implementing the project during the learning methodology. Project implementation, problem-solving, and design optimization are essential for an engineering student's overall growth. They focus only on the concept relevant to the contextual project, which may leave other tools unexplored, and they may need more time to explore the theoretical concepts, which are vital for engineering studies.

Multifaceted process: Designing is a complex process starting from circuit designing, simulation, and connecting various blocks to the final testing and working model. In experiential learning models, students engaged at each stage of development derive the learning outcomes from the designing process. Studies indicate that students may have different problems at various stages of project implementation. It is essential to mention that they may fail or end up in incorrect outputs during the implementation for many reasons. It may increase the duration of project implementation. The fixed semester is a limitation in completing the design process within the specified timeline, providing less flexibility for experimentation.

Additional expenditure: Project implementation requires components with proper electrical compatibility for circuit designing and running simulations on software tools before connecting the circuit to a breadboard. When designing, compatibility issues may arise between different components, like the failure of components due to misconnections, as students are still novice in design and implementation [32]. Few case studies also support hiring an industry expert to guide students. Hence, it is challenging to implement project-based learning without the support of funding agencies. All these factors result in additional expenditure at planning stage.

2.3.2 Assessment complexity:

Experiential learning-based pedagogies are employed to enhance the skills like knowledge of the content, designing issues, project implementation, teamwork, communication, presentation, and documentation of the work.

Students translate their knowledge into meaningful projects through experiential learning-based models. The relationship during this translation may be non-linear; only some students may do well in one part of the design, whereas others may develop expertise for other designing portions. It complicates the assessment of students as project development involves various stages, and evaluation during each stage is complex.

Students learn to support each other and guide each other. They also learn to seek help and understand the importance of collaboration. Project implementation is also essential to make students aware of teams, organizational behavior, communication skills, and documentation skills. Assessment of these skills requires keen observation and knowledge of organizational behavior. Thus, it creates an additional requirement of developing rubric to bring uniformity in assessment process.

2.3.3 Development of supporting tools:

Monitoring of Students' Progress: Project-based and learning-based studies require the development of specific web-based tool for keeping track of student enrollment, laboratory management, examination planning, grading of the project, and progress monitoring. When these tools are developed specifically for the experiential learning activity, they are an additional burden on the members of faculty.

Complexity in Game-based learning: Game-based learning requires designing specific games for the courses. Development of these games requires a huge technical understanding of game design and content. Also, these learning techniques are appropriate for computer-based subjects but difficult for less computer-friendly courses. Game-based learning requires high skills of innovation. Sometimes, specialized training is required to learn innovative teaching for imparting the skills with the help of game-based learning tools [33]. When purchased through vendors, these tools are an additional monetary load on the institute.

2.3.4 Other Prominent issues:

High dependency on members of faculty: All the major case studies need funding from different agencies initiated by members of faculty working as educators. These educators are keen to change the traditional teaching mode and make learning more effective by approaching new pedagogies. To bring these changes, they must ensure the development of students' skill sets. Accepting and completing these activities require a lot of enthusiasm, motivation, and dedication.

Ethical issues in experiential learning: Ethical issues that can occur in experiential learning include inadequate information about student's choice, inadequate briefing about design and its implementation, role of personal behavior, the negative impact of feedback, and the degree of boundedness of experiential activities [34].

3. Trajectory-based pedagogy for Effective Content Delivery and Evaluation of Students' Knowledge and designing of adaptive assessment

Based on the limitations discussed, this paper proposes a trajectory-driven pedagogy. In the program structure of Amity University, Program learning outcomes are mapped with the outcomes of course objectives. Course objectives are extracted from the course structure which define the course's prerequi-

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sites. Hence, mapping of program learning outcomes truly evaluates the students' performance when a course and its prerequisites constitute the complete knowledge structure of central concepts.

3.1 Research Objectives:

The main objectives for this work are:

(i) To introduce a teaching pedagogy which integrates the existing teaching methods and experiential learning-based methods.
(ii) To design the computer-based adaptive assessment for the proposed teaching method for evaluation of students' learning.
The most fruitful outcome of examining the experiential learning methods comes in the form of associative learning. As students learn through project designing/implementation, problem-solving, or gaming, they use only some of the concepts of a single course. However, they apply the concepts of the courses associated with that course primarily as the prerequisite courses [35].

3.2 Teaching Methodology: ‘Trajectory-based pedagogy' introduced in the pilot study for engineering course:Engineering students learn the courses independently and are evaluated solely for the current course. Students score well in the end-semester examinations, and their performance could be the outcome of rote learning in an individual course where students memorize the contents without understanding the concepts. To embed the underlying concept and evaluate knowledge, a solution to the research objectives are:
(i) Introduction of a 'trajectory-based' teaching pedagogy that can blend within the existing curriculum.
(ii) Framework of computerized adaptive assessment methods that would complement the trajectory-based teaching pedagogy for measurable outcomes of students learning.
Experiential learning based on 'trajectory driven pedagogy' is based on the association of knowledge as a trajectory of courses between the current course and its prerequisite courses. In the program structure of undergraduate courses in engineering, a study of each course needs prior knowledge of prerequisite courses. If a student can retain the knowledge of prerequisite courses while studying the current course, it will develop a strong knowledge of the underlying concepts.
In the pilot study, a framework between a 'trajectory' of courses consisting of Power Plant Instrumentation (PPI) in the seventh semester of the undergraduate engineering program of the department of Electrical and Electronics, Transducers and Application (TAA) as the first prerequisite course studies in the sixth semester of same program and Measurement and Measuring Instrument (MMI) as the second prerequisite course studies in the fifth semester of the same program. In the course structure of PPI, both prerequisite courses are mentioned.

3.2 Introducing quantitative 'Learning Coefficient' through Trajectory-based Assessment System
The developed adaptive assessment system would calculate the learning coefficient to quantify the assessment as an active measurement tool from trajectory-based assessment. The evaluation scheme was based on an adaptive multiple-choice question paper, following the trajectory of courses discussed in the previous section. In the adaptive assessment, questions are not generated randomly. The questions are based on correct or incorrect response of the student.
After certain sets of questions, the measurement of the performance as a coefficient would map with the learning outcomes, thus quantifying the assessment process.

3.3 Designing of Trajectory-driven Adaptive Computerized Assessment Tool
The existing computerized adaptive systems have questions' difficulty levels within the same course [36-37]. The system is an intelligent adaptive system, as shown in Figure 1, where an intelligent search algorithm is the assessment tool. The questions appear as the trajectory of questions from the pool of courses in the defined trajectory. The proposed system has following users:
Course Expert
Question Paper Setter
Student
The system workflow includes verifying user IDs for students and course instructors and uploading questions based on the given Trajectory of courses.

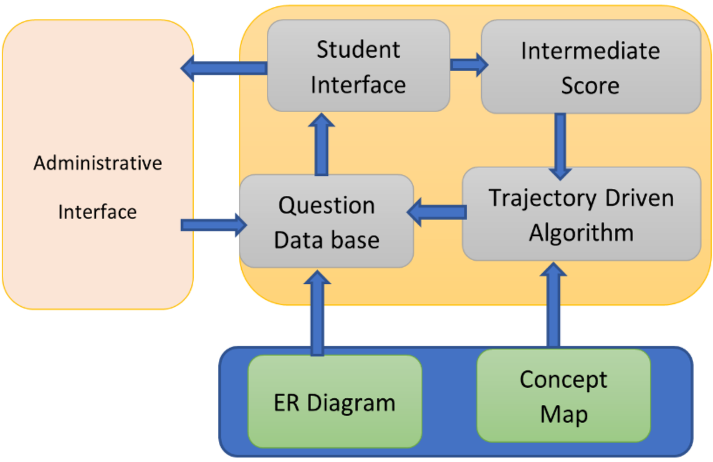

Figure 1. Framework for Computerized adaptive assessment.

4. Experimental setup for the development of computerized adaptive assessment
Adaptive computerized assessment is still in the process of development. The assessment conducted for this study was adaptive, but the answers were evaluated manually based on the search algorithm. This section discusses a framework for designing the proposed assessment tool. An adaptive assess-

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ment system requires a proper sequence for generating the questions. Designing an online platform for assessment is explained with the help of an entity relationship diagram along with a concept map which shows the path of generating questions in a proper sequence.

In this study, the pattern of question generation in adaptive assessment for a particular topic (Temperature measurement in the Steam Circuit) of PPI is illustrated with concept map. Further, questions will cover the types of instruments, their range of measurement, their classification, and their characteristics.

4.1 Data Collection based on Evaluation Metrics:

The department of Electrical and Electronics Engineering conducted an assessment on the undergraduate students of seventh semester. These students have to study the courses PPI, TAA and MMI in the seventh, sixth, and fifth semesters respectively. For the study, these three courses formed a 'trajectory'; TAA and MMI are prerequisites of PPI as given in the course structure. This assessment was formative, where the performance will not affect the final evaluation of the students. The adaptive assessment is a formative assessment in which acquired scores provide feedback to the students regarding their learning assessment without including them in the calculation of SGPA. This activity was not mandatory, and nine students voluntarily participated in experiencing the new teaching pedagogy. Conducted assessment questions paper consists of 10 sets of three questions that appeared in a trajectory based on the selected courses as PPI→TAA→ MMI in each set of questions. The question paper consists of multiple choice-based answers. A correct answer will score 1; otherwise, 0.

4.2 Trajectory-based Search Algorithm

The trajectory-based search algorithm would generate subsequent questions based on the score of the current question for calculating the learning coefficients as *a*, *b*, and *c*. a, b, and c are the scores corresponding to the questions from the courses X, Y, and Z, respectively. X is Power Plant Instrumentation in the Seventh semester, Y is Transducers and Applications in the sixth semester, and Z is Measurement and Measuring Instruments in the fifth semester.

X_i – {Questions from Course X}

Y_i – {Questions from Course Y}

Z_i – {Questions from Course Z}

$a_i = \{a_1 \ldots. a_s\}$: Score corresponding to X

$b_i = \{b_1 \ldots. b_s\}$: Score corresponding to Y

$c_i = \{c_1 \ldots. c_s\}$: Score corresponding to Z

Scores a, b, and c are either 1 or 0.

The flow chart for the generation of the learning coefficient is shown in Figure 2:

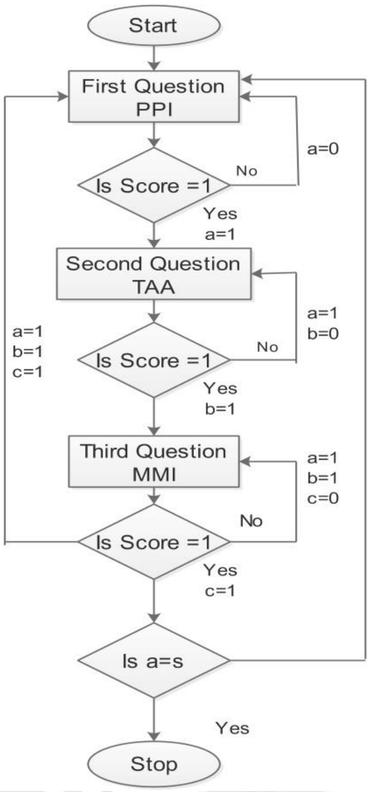

Figure 2. Flow chart for trajectory-based search algorithm

4.3 Entity Relationship Diagram for the case study

Entity-relationship diagrams represent a relationship between various entities that constitute the complete database. These entities consist of many attributes that describe them. These diagrams are particularly useful for storing extensive data in relational database management systems. Figure 4 shows the database showing the storage and relationship between various entities of a database, namely, Question, Course_id, Course Instructor, QPD (Question Paper Database), and Question Paper. The question has attributes, Q_id, Status, Current User, and Topic from which the question has appeared. The question entity is related to the Course Instructor whose attributes are User_id, Name, Course_id of course taught by the instructor and their department as Deptt.

The question paper is designed from the question paper database. It has attributes such as user_id of the course instructor, question _id, deptt, a course on the question, and many question papers generated from the question paper database. The question paper has attributes such as the year of uploading the question paper and skills evaluated through an assessment. Numerous question papers are generated from the question paper database. This relationship is explained in Figure 3.

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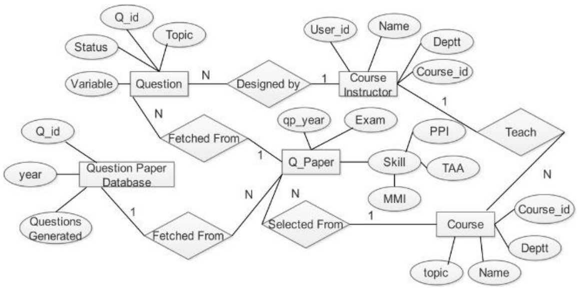

Figure 3. Entity-relationship diagram of proposed framework

4.4 Concept map for selection of questions of selected courses

A concept map is a diagram that shows the relation or flow between different ideas. The concept map shown in figure 5 was created with the online tool Cmap [38-39]. It shows the sequence of questions and the temperature measurement hierarchy in power plant steam circuit. As shown in the concept map, the flow of questions shows the temperature measurement in the steam circuit at the power plant, as a variable attribute of entity, ‘Question,’ in ER diagram (figure 3). Questions will be based on following points:

-Applicability of transducers in the circuit, their types, and range.

-Type principle of measurement of a variable parameter that would be measured as voltage or passive element measurement.

-Type of analog or the digital measuring instrument used for measurement.

-Characteristics of measuring instruments.

Each trajectory consists of three questions, where each question has a standard variable as studied in the courses PPI, TAA, and MMI. Figure 4 shows an example of such a trajectory, where temperature measurement is a 'variable’ and questions from all three courses are related to temperature measurement.

1. These temperature sensors are used to measure circulating water in the power plant.

(a) Gas-filled thermometers

(b) Liquid-filled thermometers

(c) Electrical resistance thermometers

(d) Vapor pressure thermometers

If the answer to this question is correct then a=1 otherwise a=0;

a=0; End

For a=1, the second question appears from the course Transducers and Applications.

2. In a liquid-filled thermometer:

(a) Temperature is directly measured

(b) Thermal expansion is converted into temperature

(c) pressure is measured and converted into a temperature value

(d) Volume of the liquid is measured

If the answer to this question is correct then b=1, otherwise b=0;

b=0; End

For b=1, the third question appears from the course Measurement and Measuring Instruments.

3. A thermometer has a time constant of 3.5s. It is quickly taken from a temperature 00C to a water bath at 1000C. What temperature will be indicated after 1.5s?

(a) 500C

(b)77.80C

(c) 34.860C

(d) 33.330C

If the answer to this question is correct then c=1 otherwise c=0;

C=0/1; End

Figure 4. Calculation of the Scores for each Question in Trajectory

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Initial questions are from the PPI; then, questions will appear from TAA and, at last, from MMI to measure any one parameter. Questions will change from their application in the power plant circuit to the underlying principle used in constructing related measuring instruments.

In this example, Questions will appear as PPI→TAA→ MMI for a given set of questions; if the score of given of a given question from course X is 1, the next question from Y will appear. In case of a 0 score, the loop will end, and the default score would be 0 for that set in all three ai=0, bi=0, and ci=0 for the i^{th} question.

For a=1 and b=0, the loop will end, and the score will be a_i=1, bi=0 and ci=0/1. If bi=1 then, the next questions will be from course Z. Loop will end. The score would be a_i=1, bi=1, ci=0/1. The next set of questions will appear subsequently. Intermittent scores will be stored, and next question will appear based on their value.

Figure 5 shows the concept map for the proposed trajectory based computerized adaptive assessment for one variable, 'temperature.' Questions are dependent and are selected on the topics explained in the concept map from each course selected for this work.

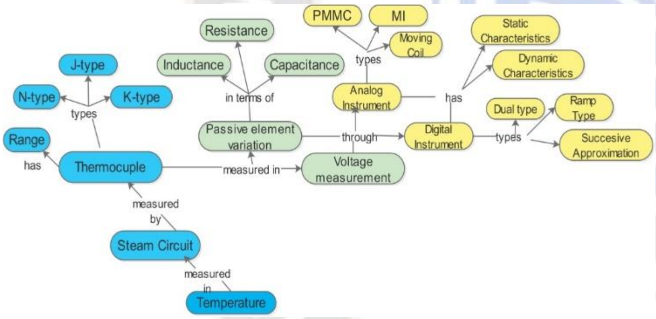

Figure 5. Concept map relating to the various topics for mapping questions

4.5 Learning coefficient and evaluation metrics

Scores against each question are stored as a, b, and c, respectively, as shown in Figure 7. These scores calculate learning coefficients J, K, and L as the average values of an, bn, and cn, respectively.

$$J = \frac{a1 + a2 + \cdots an}{n} \quad (1)$$

$$K = \frac{b1 + b2 + \cdots bn}{n} \quad (2)$$

$$L = \frac{c1 + c2 + \cdots cn}{n} \quad (3)$$

J, K and L are calculated from the scores in selected courses using Eq. (1), (2), and (3) respectively. J, K and L are used as evaluation metrics that would be analyzed to measure the performances of students. These metrics are calculated for both paradigms– for regular item response theory-based assessment and for trajectory based adaptive assessment. These evaluation metrics act as learning coefficients which give quantitative valuation for each course.

5. Results

A total of 9 students participated in the assessment. Questions appeared from each sequence in the sequence shown in Figure 4. Evaluation methods used are trajectory based adaptive assessment based on the algorithm explained in figure 2 and regular IRT (Item Response Theory) mode, where each correct answer scored one mark irrespective of the score of the previous question in the set. Comparing the two evaluation methods shows a difference in performance in both methods. Adaptive assessment enhanced the difficulty level of the questions paper; this section discusses the results of the two modes of evaluation.

5.1 Graphical analysis of the assessment process

This section compares two assessment methods: evaluation conducted on regular IRT-based assessment and proposed trajectory based adaptive assessment.

5.1.1 IRT-based evaluation:

In regular IRT-based evaluation, each correct answer fetched a score of 1. The score against each course has been averaged as in Eq. (1), (2), and (3), respectively.

Graphical analysis shows that there is less variation in the IRT-based assessment. These are the absolute scores of performances in each of the courses.

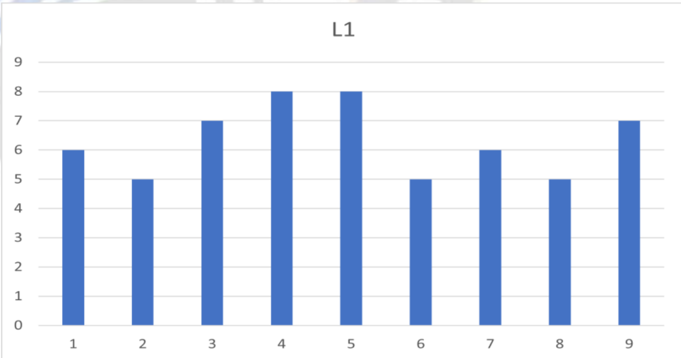

Figure 6(a). Scores for each course for IRT-based evaluation (PPI)

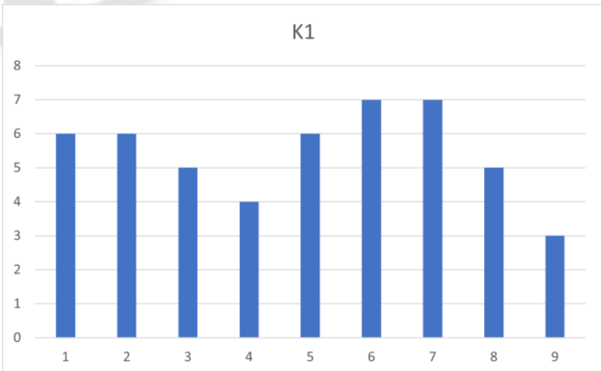

Figure 6(b). Scores for each course for IRT-based evaluation (TAA)

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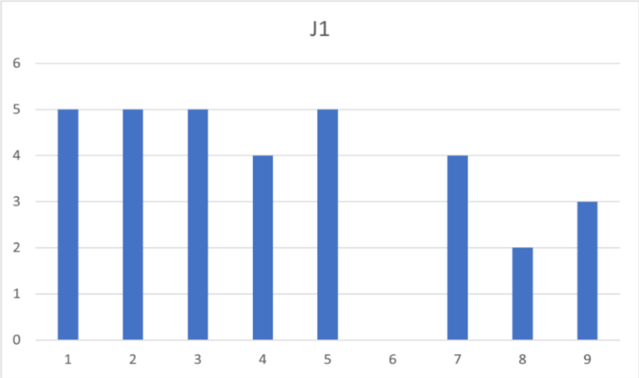

Figure 6(c). Scores for each course for IRT-based evaluation (MRI)

Each correct answer scored 1, and an incorrect answer scored 0 in the question paper that consists of 30 questions, ten questions from each of the three courses. For every course, average scores were the cumulative score of ten questions. The range of L1 is between 5 to 8 for the PPI, K1 ranges between 3 to 7 for TAA, and J1 is between 0-5 for MMI, as shown in the graphs of Figure 6(a), 6(b) & 6(c).

5.1.2 Trajectory-driven adaptive assessment

L, J, and K are the metrics for the trajectory based adaptive evaluation. The question paper consists of 10 sets of questions, where each set has one question from PPI, TAA, and MMI, respectively. This evaluation method calculates scores, as shown in figure 2. For one correct answer of PPI (score=1), the next question from the TAA was evaluated, and for an incorrect answer (Score=0), Scores of PPI, TAA, and MMI for questions in the given set would be 0. The process will be repeated for the correct answer of TAA (score=1), the next answer from PPI is evaluated, TAA (Score=0), then PPI (Score=0). This evaluation is based on the associative learning. Figures 7(a), 7(b) & 7(c) show the student's evaluation of the assessment of the proposed algorithm.

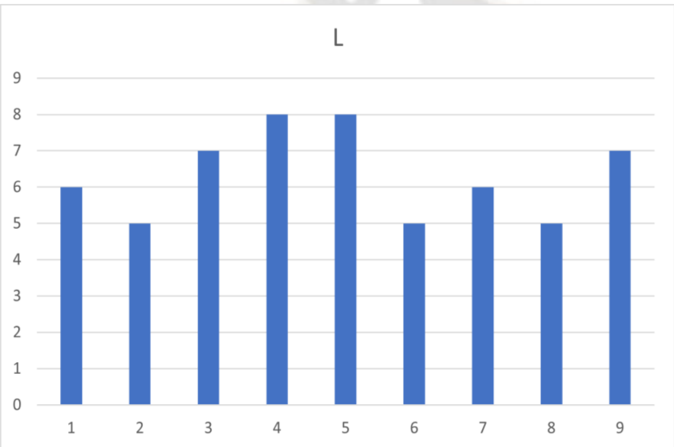

Figure 7(a). Scores for each course for Trajectory based evaluation (PPI)

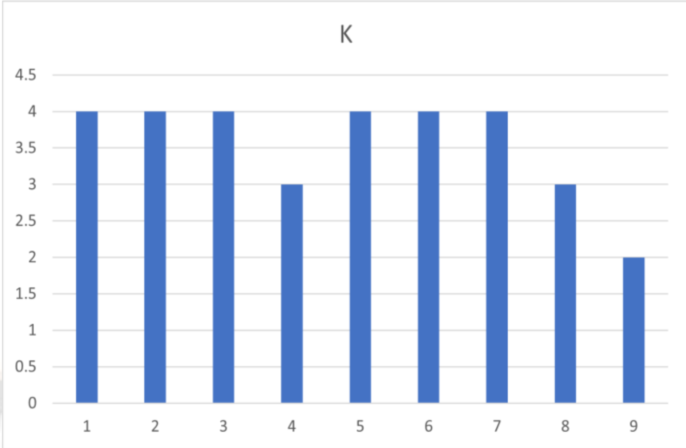

Figure 7(b) Scores for each course for Trajectory based evaluation (TAA)

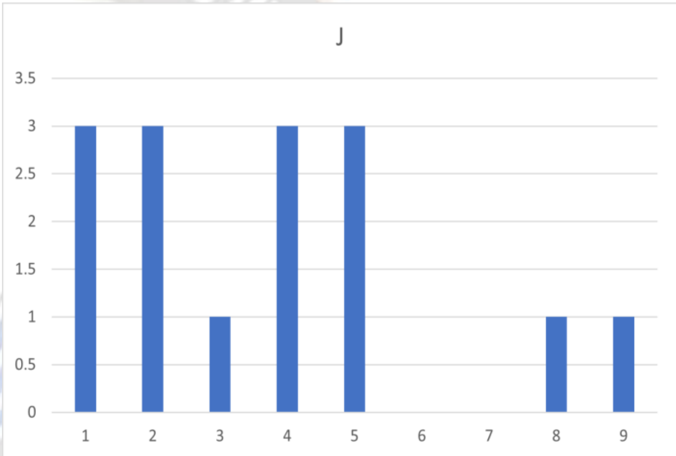

Figure 7(c) Scores for each course for Trajectory based evaluation (TAA)

Here, a decline in the student scores is evident as scores of each question in the set were not evaluated independently but based on the answer to the previous question for the given set of three questions based on trajectory. Graphical analysis shows that learning coefficient L is the same as L1 but decreasing scores in consequent courses as K ranges between 2 to 4, and J is just between 0 to 3.

L1, K1, and J1 are the scores in IRT mode. L, J, and K are the derived values of the learning coefficient based on trajectory-based adaptive assessment.

5.2 Comparison of standard deviations in trajectory-based and IRT-based methods

Table I shows the standard deviation of the learning coefficients in both methods of evaluation in the assessment. The value of standard deviation is higher in trajectory based evaluation method. Students did not score well when the assessment included a performance in past questions. A greater standard deviation value shows the increased deviation between the scores of consequent courses explaining the poor achievement of the leaning outcomes. A large standard devia-

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tion indicates the learning gap in the knowledge of the courses selected in the Trajectory.

Table-I Calculation of SD to compare the two methods

Scores	**Mean of IRT-based Scores**	**Learning Coefficients**	**Mean of Learning Coefficients (trajectory-based Scores)**
L1	6.3	L	6.3
K1	5.4	K	3.5
J1	3.6	J	1.6
SD (σ)	1.122		3.34

5.3 Interpretation of the evaluation metrics

L, J, and K are the derived values of the learning coefficient based on Trajectory-based Adaptive Assessment.
Table I shows an average value of L =6.3, J= 3.5, and K=1.6, respectively. It indicates that students have performed well in the current semester than in the courses studied in the subsequent semesters. Results also point to a serious issue that even without recollecting the basic knowledge, students can score well, and hence it should be an area of concern for the system.
Table I contains the mean values of the IRT-based assessment and learning coefficients calculated in the adaptive assessment. Lesser scores indicate that students cannot retain the learning in the subsequent semester. The standard deviation value for both mean values of IRT-based scores and Learning coefficients implies that in an assessment based on a trajectory-based examination, students' performance deviated primarily in the prerequisite courses. It means that students have better grades in the PPI but have not performed well in TAA and MMI courses. Average scores indicate that students are not well versed with the underlying concepts that are foundations for the knowledge of topics of PPI. Students have not performed well during TAA, and MMI, even when taught with the new approach of trajectory driven pedagogy. They knew that the grades scored in this study would not be included in their final cumulative grades.
Thus, the proposed computerized adaptive assessment method quantitatively measures the learning outcomes based on the trajectory driven pedagogy. This way, a numerical value of the learning coefficient would be achieved. A student's assessment must include knowledge of the prerequisites. Students build structural knowledge logically and sequentially with a fair recall of basic subjects. Through trajectory-based pedagogy, students studied the courses with a meaningful association between the three courses. The evaluation scheme assessed their performances in terms of the achievement of learning outcomes.

6. Conclusion and future aspects

Experiential learning-based teaching methods are prevalent in engineering education. The major challenges in implementation of these methods are university's efforts, teaching fraternity, students in planning, finances, expertise, and perseverance.
As a solution, a trajectory driven pedagogy is proposed based on associative learning as a motive for experiential learning. When taught as an association between the current course and its prerequisites, a course would embed the concepts hierarchically in students in engineering application. 'Trajectory-driven computerized adaptive assessment' can evaluate the students learning based on the trajectory selected in the content delivery.
The standard deviation value is 3.34 in the trajectory-based assessment and 1.6 in the regular IRT-based assessment. A greater value of standard deviation value shows the increased deviation between the scores of consequent courses explaining the poor achievement of the learning outcomes. It means that students could not score well on the same questions while assessing their performance on past questions.
This pilot study has successfully established that a trajectory-driven pedagogy can be merged with the existing teaching-learning methods. Adaptive assessment designed for this pedagogy has successfully calculated the quantitative learning coefficients as the evaluation metrics of students' knowledge.
The proposed method is an intelligent method of assessment which does quantitative measurement of learning outcomes based on the scores obtained by the students during assessment. The proposed method will not need any significant shift in infrastructure but a slight modification is required while designing the course curriculum. Which can be done with the help of an expert in a specific domain, making it suitable to be integrated into existing teaching-learning methods. It is suggested that the proposed pedagogy can also be employed for other courses, and assessment must be conducted as a summative assessment to achieve the maximum benefit in knowledge gain.

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