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OBE Framework for Assessing Laboratory / Practical Courses in Engineering Programmes

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Abstract : Irrespective of the branch of study, practical/laboratory courses are integral parts of engineering curriculum. These courses develop the knowledge, skill and attitude of the graduates. It is thus necessary to frame the laboratory experiments, to create a student centric learning environment and to have suitable assessment methodologies to enhance the cognitive, affective and psychomotor skills of the engineering students. This paper proposes a framework of the above three from the authors' perspective for a software laboratory. The proposed framework can be extended to the laboratory/practical with suitable modifications in the Course Outcomes. Also in this paper, a methodology is proposed for converting the scales into marks and also the formula for calculating the marks under various heads (record, viva voce and experiment) is given. Rubrics are defined for the Performance Indicators (PIs) as specified in the Examination Reform Policy of AICTE for the Program Outcomes (POs defined by National Board of Accreditation (NBA), India).

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1. Introduction

Laboratory experiments can be classified into four groups as open-ended experiments where the algorithm, procedure and implementation are done by the students through handholding. Semi open experiments are one in which the algorithm or procedure is stated and the student has to perform the experiment on one's own and must collect the observations, analyse the observations and derive conclusions from the observation. Also, the merits, limitations, scope and applications of the experiment can be identified. The next group is the open-ended experiments where the student has to understand the problem definition, identify various solutions, analyse the feasibility of implementation of these solutions, identify the most suitable solution, implement it and obtain the observations, analyse the observation and derive the conclusions from the observed readings. Finally, a complex engineering problem is included as the last experiment of the practical courses. Here the students must frame the problem definition, identify a set solution and so on.

Devasis Pradhan (2021) discussed the effective methods for the empowerment of the performance of students undergoing Engineering course. Comparison on the traditional assessment methods and OBE, various Pedagogical methods followed in Engineering Programme, various assessment tools for OBE, difficulties in the implementation of OBE , and the various Steps to be followed for the effective Implementation of OBE in Engineering Programme were also discussed by the author [1]. Jifeng Liang (2022), proposed a novel training model based on big data analysis for the specialized professionals in electronic information science and technology. Correlation index (CI) was calculated between the demand in the knowledge required by the organization and the talent inculcated in their employees. Training candidate is identified with highest CI and trained according to the requirement of the organization. The author also developed an evaluation model based on big data for talent cultivation and a model for predicting the scores using Neural Network [2].

Genelza (2022), discussed on the various policies proposed and the various challenges faced on implementation of the OBE curriculum by philippines. The author also suggested the methods for further study of the concepts in detail and have given awareness to Filipinos about the working of the system [3]. Syeed et al (2022) implemented an OBE framework for the CSE program in Independent University (IUB), Bangladesh and have provided a direction for other Engineering programs also. The authors provided a deep insight on the following three phases. I) OBE process and its practices II) various steps involved in the development of program curriculum and the related teaching, learning, various assessment methodologies in the OBE model III) following the monitoring procedure of the academic process, assessment and accreditation for maintaining the continuous quality improvement (CQI). The proposed model can be used for tracking, monitoring, measuring and planning of OBE process [4].

Loay Alzubaidi (2017), proposed a novel comprehensive combinational approach utilizing course learning outcomes (COs) and Student learning outcomes (SOs). The proposed approach makes use of threshold, average and performance vector for assessing the CO attainment. The key performance indicators (KPIs) were used for SO attainment. This also provides a quantitative value on each COs attainment level. The author also gave an insight on the various assessment tools for measuring each course outcomes [5]. Keshav Kumar Arnepalli and Kuchu Jayasree (2022), demonstrated a tool for assessment of student level student outcomes by identifying the strengths of each individual and mapping with the individual student career progression. In this work, they have compared two different assessment tools by considering the merits and flaws at course level. One tool was question wise attainment and the other tool was student wise attainment. The tool that considers the student level outcomes was proved to be the promising one [6].

This paper also attempts to provide a useful framework for laboratory courses to the skills of engineering students. This paper is organised as follows: Chapter 2 discusses on OBE based curriculum and teaching learning in laboratory/practical courses, chapter 3 dealt with OBE based assessment, chapter 4 discusses on the course outcome attainment, conclusion with the future scope is presented in chapter 5.

2. Obe Based Curriculum and Teaching Learning in Laboratory/Practical Courses

In general, OBE starts from framing the list of experiments for the laboratory to meet the Course Outcome statements, CO-PO/PSO mapping and the methodology used for delivering the experiments [7][8].

The first step is to frame the list of experiments for the concerned laboratory along with the CO statements and CO-PO/PSO mapping matrix. Prerequisite and co-requisite requirements must also be stated in the syllabus. Irrespective of the laboratory/practical courses, the experiments can be divided into the four categories (Close ended Experiments, Semi Open-ended Experiments, Open-ended Experiments and Complex Engineering) based on the level of handholding provided by the teacher[9][10][11][12].

Number of experiments can be in decreasing order from closed ended to open ended categories and there can be a single complex engineering problem in each course. However, weightage for the marks must be in the increasing order. Assessment must be at the open-ended level where the student is allowed to formulate the problem statement. Table 1 shows the level of handholding by the teacher for each category of experiments.

Table 1: Level Of Handholding For Each Category Of Experiments

Course Outcomes/Type of Experiments	Closed ended Experiments	Semi Open-ended Experiments	Open-ended Experiments	Complex Engineering Problem
Problem Definition/Formulation (Ability to convert scenario into solvable problem statement)	Given	Given	Given	Not given
Design and development of Solution Identifying suitable mathematical formula/relationship for solving the problem	Given	Given	Not given	Not Given
Selecting a suitable algorithm Having identified the mathematical formula, various methods for implementing the same have to identified and the selection of the best algorithm based on various factors (computational complexity, scalability, robustness)	Given	Not given	Not given	Not given
Conversionof the algorithm/pseudocode in the specified programming language	Not Given	Not Given	Not Given	Not Given
Implementation of the program, debugging the errors, test cases and modifying the program if necessary	Not Given	Not given	Not given	Not given
Collecting the observations, Analysing the observed readings and deriving a conclusion based on the results.	Not Given	Not Given	Not Given	Not Given
Comment on the merits, limitations, scope and applications of the program	Not Given	Not given	Not given	Not given

As an example, list of experiments in each of the four categories for Digital Signal Processing Laboratory (B.E. ECE) is given below:

Close Ended Experiments - Generation of Periodic and non-periodic signals, Determination of Z Transform and Inverse Z Transform, Impulse response of first order and second order systems and Implementation of Linear Convolution & Correlation

Semi-Open Ended Experiments -Design and Implementation of FIR and IIR filter, Determine the frequency contents of a continuous-time signal in the discrete-time domain (Spectral Analysis), Design and Implementation of Sampling & Reconstruction, Design and Implementation of Circular Convolution

Open Ended Experiments- Design and simulation of Modulation & Demodulation, Design and Implementation of Discrete Fourier Transform & Inverse Discrete Fourier Transform.

Complex Engineering Problems - Problem 1: For a certain application, it is necessary to identify a suitable thermocouple based on its frequency response. Develop a suitable code for helping the user in this scenario. Problem 2: In forensic department, it is necessary to identify the speaker from the speech signal. Develop a code for the above scenario.

The Course Outcome statements are stated in such a way that they can be made specific for any programming laboratory. These CO statements are listed below: Table 2 gives CO-PO mapping for the defined CO statements.

After the end of the course, the students will be able to

CO1: Define the problem statement for the given scenario/Real World Problem

CO2: Develop algorithms by identifying the mathematical formula/relation

CO3: Develop the program code for the selected (the most suitable) algorithm

CO4: Analyse the suitability of the implemented program code for various test cases

CO5: Develop the final version of the program by retaining the same code/by modifying the program if necessary

CO6: Examine the results to derive conclusions and to comment on the merits, limitations, scope and applications of the developed program

Table 2: Co-po Mapping For a Programming Laboratory

CO statements	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
Define the problem statement for the given scenario/Real World Problem	3											
Develop algorithms by identifying the mathematical formula/relation			3		3*	3	3	3			3	
Develop the program code for the selected (the most suitable) algorithm			3		3*	3	3	3			3	
Analyse the suitability of the implemented program code for various test cases		3		3			3					
Develop the final version of the program by retaining the same code/by modifying the program if necessary			3		3*	3	3	3			3	
Examine the results to derive conclusions and to comment on the merits, limitations, scope and applications of the developed program				3			3		3	3		3
Average	3	3	3	3	3*	3	3	3	3	3	3	3

Mapping with first four POs (which are assessing the knowledge domain) is self explanatory. For PO5 which is Modern Tool Usage, * indicates that a mapping can be done across a CO only if a modern tool is used. While developing the code or program, the student must consider the public health, safety, etc and economic perspective and hence PO6 (Engineer and Society) and PO11 (Project Management and Finance) can be mapped. In accordance with the recent trends, the code must be developed so that its lifetime is at least five years and hence PO7 (Environment and Sustainability) is mapped. Plagiarism in the code must be avoided and hence PO8 (Ethics) is mapped across those COs. Student must be capable of interpreting the results and study its advantages, disadvantages and scope of the code. Student must be capable of recording the findings in his observation and record notebook during regular class hours and also during viva voce examination with a good attitude. Hence PO9 (Individual and Team work) and PO10 are mapped with the corresponding Cos [13][14][15][16].

Having clearly planned the course delivery for the syllabus, teacher then proceeds with the student centric teaching approach where handholding is done is for close ended experiments and guidance is provided for the other two groups. Complex engineering problem is then given to the students and the teacher assesses the overall performance of the student.

3. OBE Based Assessment

Continuous assessments insist a definite methodology for collecting data from the regular laboratory experiments, model practical examination, End Semester practical Examination. In each case performance is measured in terms of student's ability to formulate/develop/implement/modify the program and his ability to record the observations, analyse the recordings, conclude the results and one's ability to answer the viva questions. In order to proceed with the assessment, it is necessary to formulate the rubrics and inform the same to the students in the very beginning of the course.

As an example, let us consider that out of overall 50 marks allotted for End Semester Practical Examinations, 30 marks are allotted for Written Examination (WE), 10 marks are allotted for Viva voce Examination (V) and 10 marks are allotted for Record notebook (R). Sample rubrics for the assessment of PO1, PO2, PO3, PO4, PO5, PO8, PO9, PO10 and PO12 along with their impact on the calculation of marks under three heads (WE, R and V) are explained in Tables 3 and 4.

Table 3: Sample Rubrics for PO1, PO2, PO3, PO4, PO5, PO8, PO9, PO10 and PO12 and Corresponding Marks (out of 50)

Performance Indicators (Examination Reform Policy, AICTE) /scales	Poor (0)	Fair (1)	Good (2)	Excellent (3)	Marks
1.4.1	Shows minimal or no ability to apply engineering concepts	Shows ability to use some Electronics engineering concepts	Able to apply most of the Electronics engineering concepts to solve engineering problems correctly	Shows skilful 3 ability to apply all the suitable Electronics engineering concepts to solve engineering problems correctly	(WE)
2.4.4	Shows no interest in drawing the conclusions	Shows interest in extracting the conclusions and could extract few conclusions	Identifies the correct conclusion statements and limitations but could not relate to the objectives	Identifies the correct conclusion statements and limitations and relate to the objectives in a consistent manner.	3 (WE)
3.4.1	Shows minimal or no ability to refine conceptual design in to a detailed design	Has an idea towards detailed design but not with the available resources	Able to have a detailed design with available resources	Shows skilful ability to improve conceptual design in to a detailed design with the available resources	6 (WE)

3.4.2	Unable to get information from the tests	Exhibits minimal ability in getting information from the tests	Shows ability to generate information through appropriate tests with less improvisation/ revision on design	Shows ability to generate information through appropriate tests with effective improvisation/ revision on the Design	6 (WE)
4.3.3	Unable to represent data in appropriate forms (table or graph)	Uses tables/graphs to represent data but lacks ability to analyze data properly	Uses tables/graphs to represent data and analyze data properly but unable to draw conclusions	Effectively uses tables/graphs to represent data and analyze data properly and draw conclusions on the analysis	6 (WE)
5.1.1	Shows minimal or no ability in identifying the need for modern tools	Shows some ability in identifying the need for modern tools	Can clearly identify the need for modern tools	Can clearly identify the need for modern tools, explain the principle and application	3 (WE)
8.1.1	Shows minimal or no interest in identifying situations of unethical professional conduct (safety procedures, cleanliness,punctuality)	Can identify unethical conduct but could not propose alternatives	Can identify unethical conduct, propose alternative but not following it	Could clearly identify unethical professional conduct and not only propose but also follow them	6 (V)
9.2.4	Breaks down at difficult situations	Sometimes composed at difficult situations	Handles difficult situations with at most composure but could not resolve the situations	Handles difficult situations with at most composure and dignity and provides solutions to resolve the situations	3 (V)
10.1.1.	Unable to read or interpret the information	Reading and understanding is limited to technical information only	Reading and understanding is not limited to only technical information but also to non -technical information	Shows skillful ability in reading, understanding and interpreting both technical and non - technical information	3 (V)
10.1.2	Unable to write a report adhering to standards of engineering documents	Can produce few concepts as clear, well constructed manner.	Most information is presented in a clear, well constructed manner.	All information is presented in a clear, well constructed, logical, interesting, well supported with engineering documents and novel sequence and is easyto follow.	6 (R)

12.1.2	Shows no or minimal ability in identifying the deficiencies	Shows ability in identifying the deficiencies but lacks knowledge in identifying information to close the gap	Shows skillful ability in identifying the deficiencies and shows some proficiency in identifying information to close the gap	Shows skillful ability in identifying the deficiencies and shows extreme proficiency in identifying information to close the gap	5 (V)

Table 4 : Rubrics To Mark Conversion For Written Examination, Viva Voce and Record

Description/ split up	Written Examination (WE)	Viva Voce (V)	Record (R)
Maximum marks	30	10	10
Performance Indicators	1.4.1, 2.4.4, 3.4.1, 3.4.2, 4.3.3, 5.1.1	8.1.1, 9.2.4, 10.1.1,12.1.2	10.1.2
Formula	Marks_WE=(Total_WE/27)*30 Where Total_WE=(Scale_1.4.1/3)*3 + (scale_2.4.4/3)*3 + (scale_3.4.1/3)*6 + (scale_3.4.2/3)*6 + (scale_4.3.3/3)*6 + (scale_5.1.1/3)*3	Marks_V=(Total_V/17)*10 Where Total_V=(scale_8.1.1/3)*6 + (scale_9.2.4/3)*3 + (scale_10.1.1/3)*3 + (scale_12.1.2/3)*5	Marks_R=(Total_R/6)*10 Where Total_R=(scale_10.1.1/3)*6

4. Course Outcome Attainment-a Discussion

Data collected as discussed in Section 3 is used for the calculation of direct attainment of Course Outcomes and a Course End Survey can be used for obtaining data for the calculation of Indirect Attainment of Course Outcomes. Course attainment procedure must also be well defined and approved by the appropriate committees at the program level and department level. Though there is no hard line in fixing the thresholds and levels for the attainment of Course Outcomes. However in general, the ratio of direct to indirect attainment is 80to 20 in percentages. Also while calculating the direct attainment, three different levels of attainment are kept as 0,1 and 2. Threshold levels and the number of students securing a particular window are fixed by the programme based on the previous year performance. Also the courses are classified into three groups namely ‘easy’, ‘medium’ and ‘Difficult’ and the thresholds and windows are different for different difficulty level of the courses. Having unique threshold and window levels for each course is not impossible.

5. Conclusion and Future Work

In this paper, OBE based curriculum, OBE based teaching learning and a framework for OBE based assessment of laboratory courses is provided in authors’ perspective. A mapping between the rubrics and marks is also provided along with the Course Outcomes and Course Outcome-Program Outcome articulation matrix. As the conventional mark split up is an even number not divisible by 3, at least for one Performance Indicator, the allotted mark is not divisible by three which needs an approximation (as the scales are 0,1,2 and 3). This can be avoided if the mark split ups can be had as a multiple of 3. Though the rubrics and framework is provided for software laboratory courses, the same can be customized for laboratories/practical with hardware experiments.

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Game-based Teaching Methodology for Active and Informal Learning

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Abstract: It is difficult to keep learners engaged in the classroom. Teachers need to innovate new ways to keep them active. The most common pedagogic methods require learners to be familiar with course terminologies and phrases. They may even require in-depth knowledge of the concepts at times. However, a small number of pedagogic techniques have been developed to ensure that learners understand basic terminologies and phrases, and the relationships between them. This paper fills that gap by introducing a novel game-based pedagogic technique. Findings based on scores of participating and non-participating learners show that participating learners understood the important terminologies, phrases, and their relationships in the courses very well. The non-participating learners had difficulty remembering the relationships between terminologies. Experiments have shown that when innovative learning methodologies are used in the classroom, learners understand the important words and concepts better. ANOVA one-factor test suggests that learners have benefitted from this game-based pedagogic approach.

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It was discovered that gamification aids learners in remembering and relating terminologies and phrases. This method has resulted in better teamwork and comprehension. Gaming, as a pedagogic technique, to learn a course helps build creative, ingenious and pioneering thinking. It builds critical-thinking abilities among learners.

Keywords: Active learning, engineering education, game-based pedagogic technique, gamification, innovative teaching-learning

1. Introduction

The primary objective of engineering education is to impart learners (also known as students) the required knowledge to practice engineering. The teachers need to focus on developing an engineering mind-set among learners which would enable the learners to devise solutions for complex engineering problems in future. In order to achieve this goal, the teachers need to come up with innovative ways of teaching. Online courses play an important role in learning.

Gen Z is comfortable learning online. Online courses having high demand in the industry are preferred for studying by this generation. These courses do help learners acquire the knowledge. Learners can learn at their own pace from videos as many times as they want. Efforts are being made to support and facilitate online learning (Ferdig et al., 2020). However, a personal touch and customized teaching makes a lot of difference in learning. Hence, classroom teaching cannot be replaced by any other mode of teaching.

In addition to this, the teachers need to understand that the attention span of students is low. In general, although the attention span is said to be 10-15 min, the teachers need to take into account individual differences in attention spans of students (Wilson & Korn, 2007). Engineering education has a large number of conceptually and mathematically heavy courses. Concentrating for the entire one-hour lecture is strenuous. Therefore, it is very important for the teachers to keep students engaged and attentive through innovative ways of learning. Redesigning classroom lectures becomes inevitable. Innovative methodologies are required to be developed.

Traditionally, engineering education is equipped with laboratory courses. Laboratory courses help students "learn by doing" (Edward, 2002). Use of active learning techniques has been demonstrated earlier (Chen & Cheng, 2007; Hakimzadeh et al., 2011; Hao et al., 2018). The students learn to follow deadlines, improve their skills, develop critical thinking abilities and develop their own solutions to the problems. The students understand that there are different ways to solve a problem, thereby, acquire problem-solving skills.

Engineering challenges are increasing day-by-day. The gap between multiple disciplines is decreasing day-by-day. Even a medical domain needs computer application, mechanical engineers need knowledge of electronics and electronic engineers need to study specialized fields like Artificial Intelligence (AI) and Machine Learning (ML). As a result, inter-disciplinary knowledge is a must, nowadays. Classroom teaching techniques must be revitalized.

Engineering education is a blend of various theories, techniques and skills. To grasp different concepts, it is important to imbibe "modular systems thinking" (Mahadevan, 2015). Modular thinking helps us divide a complex system into smaller and simpler parts. On the other hand, using smaller parts and establishing a relationship between those smaller parts, a larger and complex system can be constructed. This skill is helpful in building entity-relationship diagrams in Database Management Systems, for developing various system models in Software Engineering and modularizing programs in programming languages such as C, Python, and Java. The main objective is to be able to establish relationships between different concepts.

Information transfer does not mean education (Wankat & Oreovicz, 2015). Rote learning is not effective in engineering. Engineering educators need to develop inferential learning skills among students. The engineers need to take decisions in familiar and unfamiliar situations to solve problems. Developing problem-solving strategies among engineers is the aim of engineering education (Newstetter & Svinicki, 2014). The classroom teaching does not give a favorable environment for nurturing such abilities.

The primary objective of engineering education is to make engineers globally competent. This needs students to have an ability to solve problems without assistance. In-depth knowledge of core courses plays a crucial role. It is challenging for the teachers to make their courses interesting. Moreover, all the engineering courses have abstract concepts. Considering these requirements, engineering students need to have following abilities:

a) Ability to think logically.

b) Ability to apply appropriate techniques.

c) Ability to apply apt reasoning while solving a problem.

d) Ability to solve a problem considering the constraints.

These skills can be hardly addressed in traditional classroom teaching approaches. In this context game-based teaching is considered to be one of the best platforms from students' perspective. This paper discusses a game-based on spies and the clues, a novel active learning technique that was adapted for ML and Theory of Computation (TOC) courses for Information Technology (IT) Program. The paper further analyses its effects on learning.

Next section presents the related work on various pedagogic techniques adapted primarily in Computer Engineering (CE) and IT programs. Pedagogic techniques employed in other engineering disciplines and finance domain are also presented. Section III discusses the methodology. Section IV explains the implementation, the results and discussion. Conclusion is presented in section V.

2. Literature Review

To keep learners focused, a variety of pedagogic techniques are used by teachers. The most widely used technique is learning by programming or coding (especially for CE and IT students). Apart from this, other common techniques are flipped classroom, collaborative learning, presentations etc.

A. Flipped Classroom

In flipped classroom (FC) pedagogic technique, the teachers give an introduction to the topic in the class. Most part of the teaching (or content delivery) is done outside the classroom (Wilson & Korn, 2007; Edward, 2002; Subramaniam & Muniandy, 2019; Herala et al., 2015). For example, a URL for solving a simple (for example a one-dimensional) numerical problem is recommended for self-studying. A problem similar to the self-learned problem but more complicated (for example two-dimensional) is given to solve in the class. The activity can be extended to a much more complicated (for example multi-dimensional) problem. Instructors might prepare online lectures to introduce a topic and suggest an online lecture offered through MOOC courses for detailed discussion. The classroom time can be made more interesting by taking quizzes or building prototypes (Maher et al., 2015). This activity helps learners understand how to apply the known technique/algorithm to a more complex problem. As the learners participate in solving the numerical actively, they can establish a relationship between the known and the new knowledge. FC helps learner learn a concept in detail and apply those concepts.

(Mamun et al., 2021) have presented a concise review on the work based on FC. The researchers point out that FC has been used in the laboratory sessions and to solve engineering problems in the class rooms. FC has been blended with games and problem-based learning. The researchers point out that FC is a very effective technique and addresses challenges of pedagogic applications.

Researchers (Subramaniam & Muniandy, 2019; Aycicek & Yelken, 2018) have presented their experiments and observations on the effect of FC learning on students' engagement in the classroom. They study behavioral, agentic, cognitive and emotional effects to conclude that students undergoing FC technique are highly engaged.

Although FC is very powerful and offers flexibility to learners, it is helpful at an intermediate and advanced stage of a course. FC requires great level of self-discipline and concentration while learning. Learners need to do some preparations in advance. Thus, this pedagogic technique is not useful in the early stage of a course.

B. Collaborative Learning

Collaborative learning technique helps learners learn from each other (Chen & Cheng, 2007). They can make decisions from the knowledge gained from other learners. To encourage this type of learning, an algorithm is discussed in the class, a numerical based on that algorithm is solved and finally the learners are asked to find the hypotheses of the algorithm. The class is divided into groups. Each group is given a clue about one hypothesis. The groups are asked to discuss 'for' and 'against' those clues and come up with the statements and conclusions. This activity gives a good opportunity to learners to get good insights into the algorithm. The learners learn strengths and weaknesses of the algorithm. Collaborative learning helps learners learn through discussions.

(Tsai et al., 2011) assign the task of developing wiki pages to students. These pages are evaluated by the instructor as well as by peers. This helps peers learn from others. However, researchers have discovered that students do not learn as much by evaluating other people's work as they do by creating their own.

(Li et al., 2013) have developed an interactive game using social networking environment such as PeerSpace. PeerSpace uses point system to encourage participants. The authors have effectively used this platform for competition style programming problem. However, the authors have not analyzed the effectiveness of this approach.

Another work on collaborative learning presents the experiments on students of accounting course (Agustina 2022). The quantification of results is not done and hence the effectiveness cannot be concluded. However, the author points out that the students were active, creative and innovative. The author concludes that this pedagogic technique greatly enhances speaking skills.

This indicates that the topics involving debatable issues can be taken up through this type of pedagogic technique. Implementation of collaborative learning in classrooms requires learners to be able to express their thoughts precisely. This technique also assumes that the learner has the basic understanding of common terminology in the course. Thus, this cannot be used in the basic stage of learning a course.

C. Project Based Learning

Project based learning (PBL) is another pedagogic technique that is emerging nowadays. The students are given a real-life problem and are asked to find one or multiple solutions to the problem. The students are expected to learn by doing in PBL. PBL inculcates target-driven, adaptable, multi-resolutioner abilities among students (Patange et al., 2019). This technique, in the context of CE and IT, focuses on learning-by-doing and focuses more on coding (or doing) than on remembering the terminologies and phrases.

D. Multimedia and Gaming

Audio, video and animated presentations are other common pedagogic techniques used for teaching courses in CE and IT and many other engineering disciplines. Use of multimedia techniques provides insights into the working/behavior of the algorithms/methods. This technique helps learners visualize the concepts which can be memorized easily. Sometimes, learners also present case-studies in presentation pedagogic technique. Learners can explore the applications and present them. This technique can be effectively used to develop games and make learning interesting.

The researchers use multimedia presentations for teaching Disaster Management to the first year engineering students (Malhotra & Verma, 2020). Their statistical analysis states that learning is easy and lasting for a long time with such techniques.

(Kablan & Erden, 2008) use multimedia presentations for Mathematics and Science. ANOVA results show that such instructional techniques are useful for students to learn the concepts.

(Kuk et al., 2012) propose use of a game-based learning model (GBLm) for CE students for a topic in Computer Graphics. The authors make use of GBLm to reinforce the learning that is done in the traditional way. According to the findings of the researchers, such game-based approaches enhance the learning experiences of the learners.

(Su et al., 2021) use a game-based approach for teaching algorithms and the concepts in Data Structures. Data Structures and Algorithms (DSA) is one of the core courses for the students of CE and IT. The concepts in this course are challenging and need good amount of visualization. The authors have developed a game using software to explain the concepts. This approach needs reasonable amount of understanding of core concepts.

(Végh & Stoffová, 2017) make extensive use of playing cards to explain basic data structures such as arrays and sorting algorithms in DSA. They observe that animations help students to understand important concepts.

Many such game-based approaches are used by researchers for teaching DSA (Dicheva & Hodge, 2018). The researchers have used moveable wooden boxes and robots to teach stacks and sorting algorithms. They emphasize that visualizations and interactions help students understand and remember the concepts very well. The games have multiple levels with increased difficulty levels, so that students having varied cognitive skills find the games interesting.

(Vaz de Carvalho, 2019) propose use of Augmented Reality and Virtual Reality for active game-based teaching. They state that headsets, glasses, virtual environments, haptic devices, smart phones, motion trackers, data gloves can also be used to develop game-based applications to make the teaching-learning process fun and interesting.

The designers of the game Finanzmars discuss a simulation game for students of business administration or similar courses of study (Josiek et al., 2020). The task of the player is to use the resources on Mars, a symbolic planet in the game, profitably. The objective of the game is to generate more capital through the activities. The game helped students visualize the scenarios and learn the concepts by doing in an imaginary situation such as Mars.

The educators have presented a video game called Griddle in the paper (Cohen et al, 2017). The video game is a simulated electric grid. The players can design, schedule and operate the grid with different loads, transmission lines and various generators. The players get a chance to do hands-on experiments online and demonstrate basic skills in power system design, scheduling and operations. The authors of the paper have found that such gaming techniques are effective. They help students to understand where they need improvement.

Another game-based work in the same area discusses the framework for Serious Games (SG) in electrical and electronic engineering (Callaghan et al., 2017). SG simulates different real-world situations. The game focuses on application of theoretical knowledge to practical situations. It uses prototypes as a base for further exploration. The researchers conclude that game-based learning increases engagement of students. Such approaches ensure that students understand the concepts well and can apply them practically.

Augmented reality and virtual reality are very effectively used in game-based pedagogy for civil engineering students (Dinis et al., 2017). Through this application, students were encouraged to create virtual environments relevant to civil engineering domain. Some of the aspects students had to consider while creating virtual environments were related to safety, health, visualizations and so on. Augmented reality and virtual reality proved to be very effective for students to understand and visualize different construction parameters. The authors claim that game-based learning made it easier for participants in learning activities.

The researchers discuss a video game called Spumone, in which students need to drive a vehicle called spuCraft (Shernoff et al., 2020). The vehicle has to move in a simulated world without accident. Students learned to apply different strategies learnt in a Mechanical Engineering course. The researchers have observed that students enjoyed the game and felt it was interesting, however, the effect on conceptual understanding was not significant.

Many researchers prove that it is fun learning with games. They motivate students to learn more and keep their interests active for a long time (Garris et al., 2002; Moreno-Ger et al., 2008).

All this state-of-the-art literature emphasizes on the need to use games or game-based approaches in teaching-learning, so that learning is enjoyable. Gaming techniques help understand the terminologies, concepts visually. These techniques help learners learn the concepts by watching and analyzing the scenarios. The literature survey also presents the use and effect of game-based learning in CE, IT, Electrical Engineering, Mechanical Engineering and Civil Engineering along with Finance domain. However, almost all of the pedagogic techniques have been developed to learn concepts in depth. Basic understanding of terminologies and concepts should be given equal amount of emphasis while teaching.

The work presented in this paper does not focus much on understanding the theory, algorithms or mathematics. The work emphasizes on understanding the terminologies and phrases that are commonly used in a course. The approach helps learners remember the relationships between terminologies in a unique way. This way of learning helps learners' group together similar concepts.

The next section presents objectives and the methodology of the novel game-based active learning technique for learning and memorizing basic concepts.

3. Gamification as a Teaching Methodology

A. Objectives behind Designing the Game

The pedagogic technique discussed in this paper was used while teaching ML and TOC to third year IT students. ML is an interdisciplinary field that combines concepts not only from computer science but also from linear algebra, statistics, and probability. The learners are required to be able to relate concepts from various domains for a good understanding. TOC is purely a CE and IT based course. It focuses on building logic with the help of simple machines. It deals with the study of abstract computational machines and whether a problem is solvable using abstract computational machines. This study helps learners design solutions considering hardware and software constraints.

Learners need to understand basic concepts in these two courses. Therefore, it is very important to take some steps in reinforcing the core concepts and terminologies to improve the students' learning experience. Hence, as soon as basic concepts were covered in the class using traditional methods, it was decided to use this game-based learning strategy for both ML and TOC.

Objectives behind the game are:

1. To build critical-thinking skills of learners

2. To enable students to tell a story (in a word or two)

3. To make learning interesting and fun using a pedagogic technique.

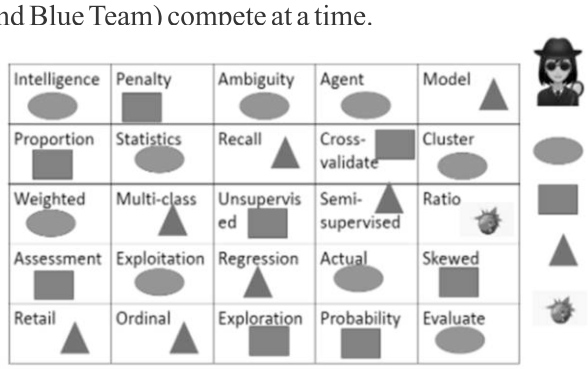
This paper promotes use of gaming as a pedagogic method for learning and revising two courses in curriculum.

B. Description of the Game

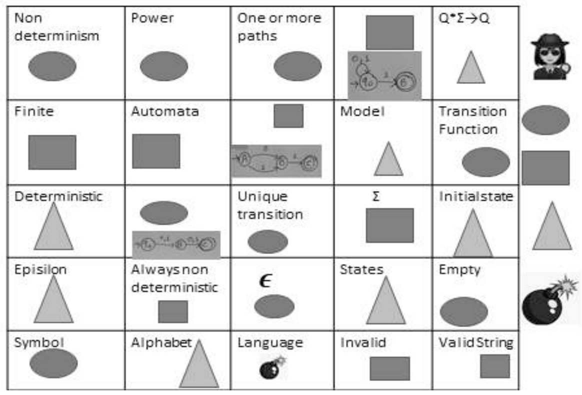
The effect of using a new pedagogic technique called 'Who wants to be a spy? Sehmat hain aap?' is studied in this paper.

The game is developed based on a card game called Codenames (Chvatil, 2015). Codenames is a Czech game developed in 2015. Two teams (each consisting of at least two people) play this game. One team member is a spymaster and he/she knows the characteristics of all the field agents i.e., the cards. The other member of the team is called field operative who has to get in touch with all field agents that belong to his/her team on getting a clue from his/her spymaster. Whichever field operative gets in touch with all his/her field agents first wins the game. The skill, that a spymaster needs to have, is to be able to build a story using the field agents or cards that belong to his/her team and give a one-word clue which points to multiple field agents or cards. The skill that a field operative needs to have is to understand the relation between the two field agents (in other words, the pattern (the clue) that describes the field agents).

'Who wants to be a spy? Sehmat hain aap?' is a game of guessing which field agents and concepts (in a given grid) are related to the clue-word given by the spymaster of the same team. Two teams (Red Team and Blue Team) compete at a time.

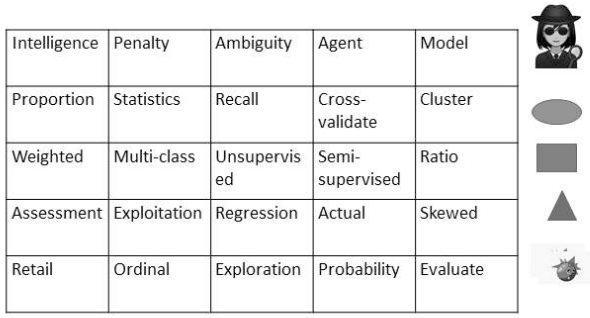


(a)

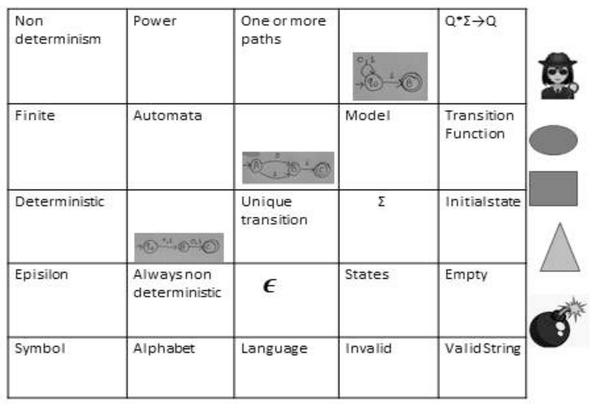


(b)

Fig. 1: Sample Spymaster's Color-coded Grid of 25 Field Agents or Cards For (a) Ml (b) Toc



(a)



(b)

Fig. 2: Sample Field Operative's Plain Grid of 25 Field Agents or Cards For (a) Ml (b) Toc

As shown in figure 1 (a), 25 field agents in ML are laid out in a 5x5 rectangular grid. A few field agents belong to the Red Team, a few to the Blue Team, a few are neutral (i.e., do not belong to any team) and one word is a bomb/killer. The spymaster is given a color-coded 5x5 grid. A sample is shown in figure 1 (a) and (b) for ML and TOC respectively. The blue ellipse indicates that word/concept/figure belongs to Blue

Team and the red rectangle indicates that word/concept/figure belongs to Red Team. The field operative gets the plain grid of the same layout as shown in figure 2. The spymaster gives a one-word clue (or two words that are most frequently used together such as Machine Learning) and the number of field agents related to that clue. Using this clue, the field operative has to identify the field agents that belong to their color. Both the teams take turns. The one who first identifies all its field agents correctly is the winner. If bomb/killer is guessed, the game ends and other team is declared winner.

C. General Framework

General framework of game design, play and experience (DPE) is prepared. Figure 3 shows the DPE framework which contains four layers: Learning, Storytelling, Gameplay and User Experience (Winn, 2009; Urgo et al., 2022; Martin-SanJose et al., 2014). Every layer contains DPE components.

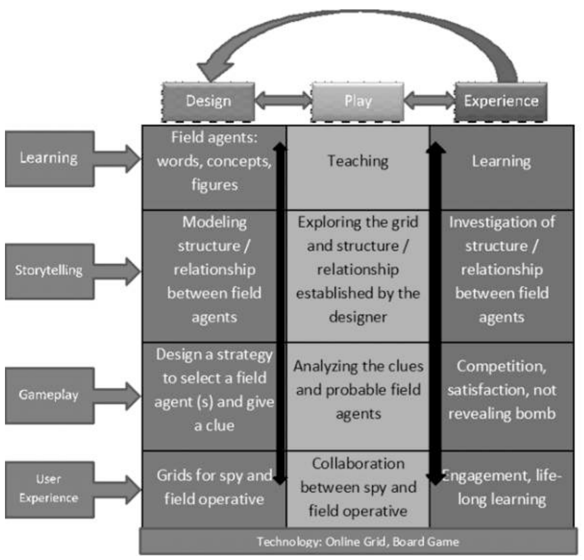


Fig. 3 : DPE framework

The framework proposed by (Winn, 2009) is adapted for game-based pedagogic technique discussed in this paper. The four layers are discussed below:

a) Learning layer: The framework defines the contents (in our case field agents) and the pedagogy (i.e. how the required knowledge should be imparted to the students and how the game should be conducted). The objective of this game was to motivate students to learn the basic concepts.

b) Storytelling layer: This layer deals with the story (i.e. the clue) used to relate the contents. The assignment of specific field agents to respective teams is done by the game designer. While playing the game, the spymaster has to explore the grid and select the field agents that belong to his/her own team to build a story (i.e. clue) so that field operative understands spymaster's intention. Accordingly, field operative has to investigate the relation.

c) Gameplay layer: This layer characterizes what the players do. They need to follow the rules of the game and interact with each other. The spymaster has to design a strategy to select the field agents and give the clue. This clue needs to be interpreted by the field operative to guess probable field agents. This inculcates competition and satisfaction among teams.

d) User Experience layer: This layer deals with the visuals that the players see (i.e. the grids). The grids should convey enough information required to play the game. Using the rules of the game, the spymaster and the field operatives collaborate with each other. The game should be engaging and must prepare the players for life-long learning.

e) Technology layer: This indicates how the game is implemented. In this case, the players only need to have online grid or if playing offline, the board of field agents.

D. Marking System of the Game

The evaluation of the game included a point system. Table 1 shows the evaluation scheme used to assess the players. For every correctly guessed field agent, the team earns one point. In case of guessing multiple field agents, the team keeps the turn. However, if the guessed field agent belongs to the other team, the team does not get any point and they lose their turn.

Table 1: Actions and the Points

Sr. No.	Actions	Points and turn
1.	Field agent not identified by the field-operative	0 point; loose a turn
2.	Every correctly identified field agent by the field-operative	1 point; keep a turn in case of guessing multiple field agents

3.	Correctly identified one field agent by the field-operative that belongs to the other team	1 point to the other team; loose a turn
4.	Guessing the field agent represented by a bomb by the field-operative	The game ends and the other team wins without accounting for the points collected
5.	Giving a clue to identify more than one field agents by the spymaster	1 bonus point if the field- operative guesses those many field agents. None for guessing a single field agent

The following scenarios help understand the evaluation process:

Scenario 1: If the spymaster gives a clue and says 1, it indicates the given clue is useful in identifying just one field agent. In this case the team gets one point for identifying the field agent correctly.

Scenario 2: If the spymaster gives a clue and says 2, it indicates two field agents can be revealed using the given clue. If the field operative identifies two field agents from the grid, the team gets three points – two points for identifying every field agent and one bonus point for giving an innovative clue by the spymaster.

Scenario 3: If the spymaster gives a clue and says 2, although it indicates two field agents can be revealed using the given clue yet only one field agent is identified correctly, then no bonus point is given.

Scenario 4: The spymaster can give one clue to reveal two or more field agents. The points are given as per Scenario 2 or 3 as the case may be according to Table 1.

Table 2: Sample Clues

Case No.	Clue	Related field agents
1.	Reinforcement Learning, 2 (reinforcement learning is a clue and 2 indicates number of words /concepts that are close to the clue)	Exploration and penalty (Red Team) and exploitation and agent (Blue Team)
2.	Innovative Reinforcement or discovery, 2	Exploration and penalty

Different cases in Table 2 show that the spymaster has to think innovatively and establish structure or relation between the two or more field agents that belong to his/her team. Accordingly, the clue has to be given. The field operative has to be alert and understand the relation that the spymaster is trying to establish. Accordingly, the guesses have to be made. The care has to be taken that the field agent belonging to the other team is not identified. Utmost care has to be taken not to reveal the bomb field agent.

As shown in Table 2, if the spymaster from Red Team says Reinforcement Learning, 2, the field operative needs to guess two field agents belonging to their team which are exploration and penalty. In this case Red Team will get three points. However, if the field operative guesses exploration and exploitation, the Red Team gets only one point. The field agent exploration belongs to Blue Team, so Blue Team gets one point.

The game has to be designed intelligently so that it is not very easy for either team to score the points. The board has to force the spymaster and the field operative to think innovatively.

4. Implementation, Results and Discussion

A. Implementation of Game

Table 3: A simple test to evaluate students' understanding of ML

Questions	Correct Answers
1. Exploration and penalty	Discovery
2. Penalty and reward	Feedback
3. You will use ------ if you know, you will be awarded	Exploitation
4. Predicting amount of rainfall is an example of	Regression
5. In 5x2 cross -validation, 2 indicates	Folds
6. In case of---- dataset, you will calculate weighted precision or recall	Skewed

7. There is no training dataset for	Unsupervised learning or clustering
8. Predicting whether it will rain tomorrow or not is an example of	Classification
9. Output is a real numberfrom $-\infty$ to $+\infty$	Regression
10. Output is from a finite set	Classification

Table 4 : A Simple Test to Evaluate Students' Understanding of Toc

Questions	Correct Answers
1. Define symbol is	Always assumed
2. Alphabets are always finite set of ---	Symbols
3. A ----- is defined by valid words and rules to make valid words	Language
4. ---- contains finite set of valid strings made up of assumed alphabets for the language	Formal language
5. ---- is defined by a lphabet set, transition state set, transition function, initial state, final state set	Finite automata
6. Unique transition is a characteristic of ---	Deterministic finite automata
7. All the valid strings for the language is the power of ---	Non-deterministic finite automata
8. Every NFA has equivalent ---	DFA
9. ---- is always non - deterministic in nature	Epsilon FA
10. ---- is empty input	Epsilon

Table 5: Comparison of scores of Group A and Group B students for ML

Question No.	Number of Correct Answers by Group A (40 students)	Number of Correct Answers by Group B (39 students)	Revised Bloom's Taxonomy Level
1	26	24	2
2	30	26	2
3	20	10	3
4	35	30	4
5	40	29	1
6	34	10	3
7	39	39	1
8	36	30	4
9	36	24	2
10	33	17	2

The following procedure was repeated for topics at introductory level in ML and TOC. Students had pre-requisite knowledge required to learn these two courses.

a) Introductory lectures to familiarize students with the basic concepts and terminologies in ML and TOC were conducted for all the 79 students studying in third year of undergraduate course of IT.

b) Out of 79 students, 40 students were randomly chosen to play the game (Group A). Remaining 39 students formed Group B. Group B students did not participate in the game. Group A was experimental group and group B was control group.

c) From Group A, 16 students volunteered to play this game online. In one-hour time slot, 8 teams (16 students) competed with each other. Different 5x5 grids were given to each pair of teams. However, remaining 24 students were also actively involved in the game and were guessing the answers using the clues given by the spymasters.

d) The 24 students were asked to share their answers through WhatsApp to the assisting teachers within 30 seconds after the clue was given by the spymaster.

e) A test was conducted for all 79 students. The questions were as shown in Table 3.

f) The above process was repeated for TOC. Groups A and B were reformed. The questions were as shown in Table 4.

B. Results and Analysis

The number of correctly answered questions by Group A and Group B students was counted. The observations are presented in Table 5 for ML and in Table 6 for TOC.

Analysis of Variance (ANOVA) is a statistical technique to find if experimental results are significant. It benefits in analyzing whether scores of Group A are different from scores of Group B. p-value helps in inferring if null hypothesis should be accepted or rejected. Following are null and alternate hypotheses used for ANOVA one-factor test.

Null hypothesis: µA = µB, where µ indicates mean and A and B indicate group A and B respectively. In other words, hypothesis states that the means of scores of tests obtained with and without playing the game are same.

Alternate hypothesis: µA ≠ µB. Alternate hypothesis states that the means of scores of tests obtained with and without playing the game are not same. In other words, there is an effect of playing the game on the mean of score.

Table 6 : Comparison of scores of Group A and Group B students for TOC

SUMMARY (ML)

Groups	*Count*	*Sum*	*Average*	*Variance*
Group A	10	329	32.9	37.21111
Group B	10	239	23.9	85.21111

SUMMARY (TOC)

Groups	*Count*	*Sum*	*Average*	*Variance*
Group A	10	285	28.5	23.83333
Group B	10	232	23.2	39.06667

SUMMARY (ML and TOC)

Groups	*Count*	*Sum*	*Average*	*Variance*
Group A	20	614	30.7	34.01053
Group B	20	471	23.55	58.99737

(a)

ANOVA (ML)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	405	1	405	6.62	0.019 2	4.4139
Within Groups	1102	18	61.2			
Total	1507	19				

ANOVA (TOC)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	140.5	1	140	4.47	0.0488	4.4139
Within Groups	566.1	18	31.5			
Total	706.6	19				

ANOVA (ML and TOC)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	511.2	1	511	11	0.002	4.0982
Within Groups	1767	38	46.5			
Total	2278	39				

(b)

Fig. 4 : Analysis of scores obtained by Group A and Group B for ML and TOC (a) Summary (b) One-factor ANOVA results

Figure 4 shows ANOVA one-factor results. P-value < 0.05 (α-value=0.05) indicates that null hypothesis should be rejected. It also suggests that there is strong evidence that null hypothesis is invalid. Also, as F critical < F value, we will reject null hypothesis. Both the above tests, suggest that observations for Group A and B are significantly different for ML. Although the values for TOC suggest that null hypothesis should be rejected, p-value is slightly less than 0.05. It is because TOC is a course which needs good amount of practice/hands-on to understand state diagrams. However, overall, the results are significant and hence this game-based pedagogic technique is influential.

The approach used in this game helps reach educational goals and objectives. This kind of gaming approach to education also supports the objectives defined by Blooms' Taxonomy (Bloom, 1956; Krathwohl & Anderson, 2010), which has six cognitive dimensions. Cognitive dimensions fulfilled by this game are as follows:

1. Remember: The first level of revised Bloom's taxonomy (RBT) is acquiring the basic knowledge and be able to remember/recollect it. The students need to remember the discussion that took place in the class in order to connect the dots between field agents. In other words, the students will be able to give/understand the clue only if they remember the concept.

2. Understand: The second RBT level is a step above remember. This level needs a learner to interpret the concept and explain in his/her own words. For giving the clue, the spymaster needs to understand the concept and give the clue in his/her own words so that the field operatives in his/her team will understand the clue. The spymaster has to rephrase the context and construct the description of the ideas.

3. Apply: The third level of RBT is about applying a concept to a new or familiar situation to solve a problem. To solve the state diagrams and equations in the grid as shown in figure 2, the students need to apply the knowledge they have regarding symbols, epsilon, loops etc.

4. Analyze: This level of RBT is regarding analyzing the concept and distinguishing between two or more concepts. The field operatives need to analyze the clues and find the probable field agents that spymaster is hinting at. The game helps students understand the difference between two or more field agents. As shown in table 2, the clue "reinforcement learning" may point at four field agents, but an intelligent clue such as "discovery" hints at only two specific field agents. Such clues develop an ability to distinguish between "exploitation" and "exploration".

Revised Bloom's taxonomy is blended in the game right from the design.

Figure 5 presents the analysis of the feedback (for ML and TOC) obtained from the students of Group A. It is evident from the graph that the students think that game-based learning helps them develop problem-solving skills as they learn to solve small problems (a few field agents) at a time to effectively solve the entire grid. Almost all the students who played the game felt that they can remember the field agents (words, concepts, figures, relations between words) in a better way. Approximately 80% students felt that they could establish a structure/relation between field agents in an innovative way. That is, they could apply their knowledge to familiar and new situations. However, many students found it difficult to interpret the clues to identify the field agents. This is because, interpreting the clues requires analytical skills to be developed. Playing similar such games can help develop analytical skills.

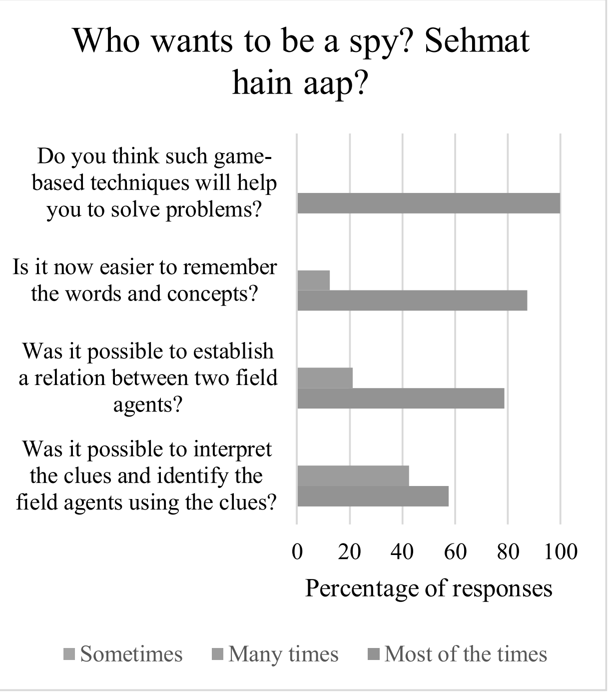


Fig. 5: Analysis of direct feedback from the students of Group A

5. Conclusion

Imparting education to engineering students is becoming challenging day-by-day. Hence, there is a need to come up with innovative ways of teaching. This paper describes a new pedagogic technique based on games. The game is based on spies who give clues to the team members called field operatives. The field operatives need to guess the field agents (words, concepts, figures etc.). This technique is deployed for two courses in undergraduate curriculum of IT.

The knowledge required to play the game was imparted through lectures. The class was divided into two groups. One group was treated as an experimental group and the other group as a control group. Tests were conducted for both the groups. ANOVA results based on the averages and variances of these tests indicate that there is a positive effect of playing the game on the participants. It can be concluded that such game-based pedagogic techniques should be used by engineering educators to make learning experience interesting and effective. It also helps in nurturing the problem-solving skills. Such game-based pedagogic techniques can help students foster their analytical skills, thereby, stimulating their thought process.

Students liked this new way of looking at technical concepts. They found this learning methodology interesting, helpful, innovative and creative. They found it refreshing and learnt a new way to co-relate the field agents where nothing might be evident. The students developed an ability to see a structure/relation.

The first four cognitive levels of revised Bloom's taxonomy are blended in this game. This game can be adapted for any course having a lot of concepts.

This game can be further enhanced to have one jackpot word that can be guessed by any team giving them bonus points. Instead of words, the grid can be formed using all diagrams to make the game more challenging.

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