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DESIGN AND IMPLEMENTATION OF AN EXPERT SYSTEM FOR STUDENTS ACHIEVEMENTS MEASUREMENT (ESAM)

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Abstract
The proposed Expert System for students' Achievements Measurement (ESAM) is a system that evaluates students' knowledge and skill attainment in a specific course by measuring their achievements of the Course Learning Outcomes (CLOs). The instructor defines the aspects, weights, and rating scale used by ESAM to analyze each course. The system calculates the average of students' marks in each learning outcome and compares them with the CLO targets and scores to determine the effectiveness of the teaching and learning methods used. The system uses facts and rules extracted from the course syllabus and Bloom's Taxonomy to build its knowledge base.
This paper presents the implementation of the ESAM inference engine, which is used to find CLO targets based on the course level. The inference engine uses efficient procedures and a prediction process to determine the correct target and score, providing a reliable and understandable methodology for reasoning about the information in the knowledge base and formulating conclusions.
ESAM is a highly responsive and intelligent system that can be a valuable tool for measuring students' achievements. Its characteristics include high performance, reliability, and intelligibility, and its combination of cognitive systems and cognitive theory has led to remarkable progress in measuring student performance.

Keywords: *Expert Systems; Interference Engine; Knowledge Base; Students' Achievements; Course Learning Outcomes*

1. Introduction

Expert system attempts to replicate the abilities of human experts in specific problem domains and is a traditional field within artificial intelligence. The first expert system was developed in 1965 by Edward Feigenbaum and Joshua Lederberg of Stanford University to analyze chemical compounds, and since then, expert systems have been used in a variety of fields such as medical diagnosis [1]. In the realm of remote medicine, decision support systems can aid in monitoring the progress of chronic wounds and detecting potential risk conditions [2]. A new decision-support methodology is proposed for monitoring and assessing the medical treatment of pressure ulcers using an expert system designed with Python packages and an inference engine [3] [4]. Course Assessment is an important criterion to determine the achievement of the students using Course Learning Outcomes (CLOs). Building an expert system to analyze of the students' performance and attainment of course learning objectives

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will help the course teacher to measure the students' achievements and evaluate the effectiveness of the course and improve the quality of the teaching and learning method in a quick and efficient way.

Course Learning Outcomes (CLOs) outline the expected knowledge that students should acquire by the end of a semester and are categorized according to the Bloom Taxonomy. The purpose of individual courses varies, with courses in the first year of a program emphasizing knowledge acquisition and courses later in the program focusing more on the application of knowledge and development of associated skills and competencies. By building an expert system to analyze student performance and attainment of CLOs, course teachers can quickly and efficiently measure student achievements and evaluate the effectiveness of their teaching methods. [5] [6].

In defining learning outcomes, learners can understand the importance of learning outcome statements in supporting teaching and learning. A learning outcome is a statement that identifies the knowledge, skills, attitudes, competencies, or habits that learners are expected to acquire from an educational experience. The Rasch model is used to measure the effectiveness of teaching and learning methods by evaluating the performance of CLOs [7] [8].

Outcome Based Education (OBE) is an innovative teaching technique that is encouraged by an education system designed to implement it [9] . An online version of the OBE system has been developed using HTML, PHP, and SQL coding [10]. Measuring the achievement of a particular CLO provides insight into the consistency of assessment tools used in measuring that particular outcome [11]. A fuzzy-classification expert system has been proposed to facilitate the learning performance of students in the domain of rehabilitation methods for cerebral palsy [12]. Additionally, an expert system application has been designed to identify specific learning disabilities in inclusion schools and provide tailored learning services, learning media, and classroom embedding for affected children [13] [14]. Finally, an expert system shell called VP-Expert has been created to automate academic advising and analysis of academic performance for students, freeing up faculty members for other important tasks [15] [16].

2. Expert System for Students Achievements Measurement (ESAM) Implementation

This paper shows design and implementation of an Expert System (ESAM) for students' achievements measurement based on CLOs achievement and attainment. Designing of the knowledge base and an inference engine to implement an expert system to measure the achievement of a particular course learning outcome can provide which course learning outcome the students have had failed to achieve. This system indicates whether the learning outcomes have been achieved consistently by the assessment or not. In addition, ESAM finds the attainment of a particular course learning outcome and guides the lecturer to monitor the students' performance and define the areas for course updates and improvement.

To assess the students' performance for the course at the end of the semester, each course is analyzed using course learning outcomes, CLOs weight in each assessment is calculated and maximum marks of CLO in each assessment are defined. The rating scale based on course level will be clarified for each course based on its level. The average of student achievements and the average of CLO achievement by assessment are calculated. Student scores in each CLO based on the rating scale will be achieved. The percentage of CLOs attainment in the course will be obtained. ESAM flow chart is showed in Fig. 1.

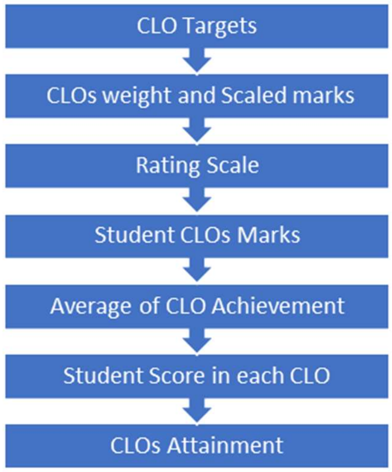

Fig. 1. ESAM Flow Chart

ESAM uses the students' marks report in a particular course. In addition, it uses the course syllabus to build a special heuristics, facts, and rules for the Knowledge Base (KB) and Inference engine. The following figure (Fig. 2) shows the major components of ESAM.

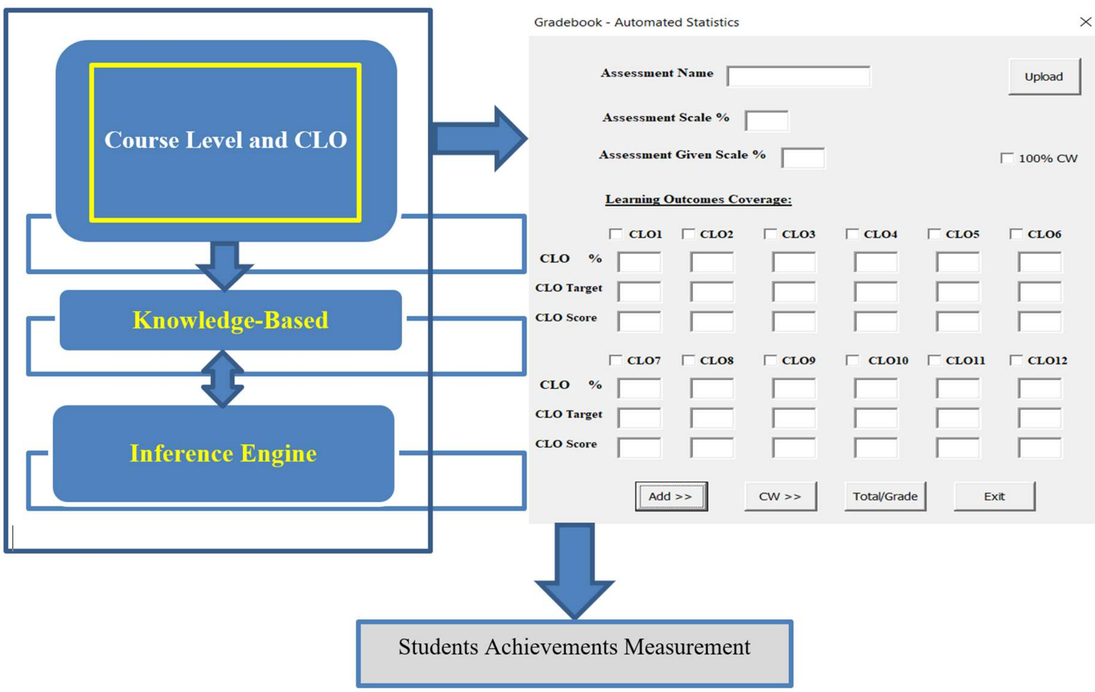

Fig. 2 ESAM Architecture

2.1 CLO Targets

The CLO target based on course level is defined in ESAM. There are different levels of cognitive learning according to the Bloom's Taxonomy. These Taxonomies of educational objectives can be consulted as useful guides for developing a comprehensive list of student outcomes. Taxonomies attempt to identify and classify all different types of learning and then defines the level of performance for each domain [17] [18]. Proposed accomplishment requirement used in the ESAM is shown in Table. 1.

Table. 1 CLOs Target

Course Level /CLO Aspect	**1**	**2**	**3**	**4**
Knowledge	70	70	75	75
Application	60	60	70	70
Critical thinking	60	60	70	70
Transferrable skills	60	60	70	70

Table.1 shows if course level is 1 and CLO is Remembering, then CLO Target is 70. If course level is 2 and CLO is Remembering, then CLO Target is 70. If course level is 3 and CLO is Remembering, then CLO Target is 75. If course level is 4 and CLO is Remembering, then CLO Target is 75.

2.2 CLOs Weights and Scaled Marks

ESAM uses the CLOs weights and scaled marks based on course syllabus. The aspect of CLOs in the assessment are defined to achieve the course level. The CLOs' score is calculated in each assessment in the course as shown in Table 2. Max and Min marks of the CLOs for each assessment will be defined based on course level. The CLO marks will be scaled as mentioned in the course syllabus by ESAM.

2.3 Rating Scale

Table.2 shows the purposed rating scale used in ESAM based on course level that assigns scores to a range of marks. The rating scale has five categories based on the minimum and maximum marks that a student can receive. The first category is for marks between 90 and 100, and students falling within this range will receive a score of 5. The second category is for marks between 80 and 90, and students falling within this range will receive a score of 4. The third category is for marks between 70 and 80, and students falling within this range will receive a score of 3. The fourth category is for marks between 60 and 70, and students falling within this range will receive a score of 2. The fifth and final category is for marks below 60, and students falling within this range will receive a score of 1.

Table 2. Rating Scale

Range of Marks	**min**	**max**	**Score**
>=90 up to 100	90	100	**5**

>=80 up to 90	80	90	**4**
>=70 up to 80	70	80	**3**
>=60 up to 70	60	70	**2**
<60		60	**1**

This rating scale is defined by the instructor in the educational institutions to evaluate the academic performance of students and is used by ESAM.

2.4 ESAM Knowledge-Based (KB)

The CLO verbs are represented as Facts in the ESAM Knowledge-Based. The knowledge base of ESAM is a store of both, factual and heuristic knowledge. Factual Knowledge: it is the information widely accepted by the Knowledge Engineers and scholars in the course syllabus and Bloom's Taxonomy. Heuristic Knowledge: it is about practice, accurate judgment, one's ability to evaluate, and guessing. The cognitive domain encompasses six domains of intellectual abilities that develop in a sequential manner, progressing from basic to more intricate behaviors [19] [20]. The knowledge base of ESAM includes the courses name and level, as well as the six levels of Bloom's Taxonomy (Remember, Understand, Apply, Analyze, Evaluate, Create) and their corresponding descriptions. The following example of KB for Math course:

```
knowledge_base = {
    'subject': 'Math',
    'level': '1',
    'learning_outcomes': {
        'remember': {
            'description': 'Recall mathematical concepts and formulas',
        },
        'understand': {
            'description': 'Demonstrate understanding of mathematical concepts and
relationships',
        },
        'apply': {
            'description': 'Apply mathematical concepts and formulas to solve problems',
        },
        'analyze': {
            'description': 'Break down complex mathematical problems into smaller parts and
identify relationships between them',
        },
        'evaluate': {
            'description': 'Assess the validity and effectiveness of mathematical solutions and
arguments',
        },
        'create': {
```

'description': 'Develop new mathematical concepts, formulas, models, or solutions',   }   }}

Also, the knowledge base of ESAM contains the assessment plan for the courses. The following example of "Computer programming" KB course:

```
knowledge_base = {
   'course_name': 'Computer programming',
   'course_code': 'XXX',
   'clos': {
      'clo1': {      'description': 'Demonstrate an understanding of fundamental programming concepts and constructs', 'weight': 22,
         'criteria': [
            {              'description': 'Write code that correctly implements basic programming constructs, such as loops and conditionals',
               'max_marks': 8
            },          {
               'description': 'Use appropriate data structures and algorithms to solve programming problems',
               'max_marks': 4
            },          {              'description': 'Apply debugging and testing techniques to identify and fix errors in code',
               'max_marks': 10
            }        ]      },
      'clo2': {
         'description': 'Design and develop software applications using object-oriented programming principles',
         'weight': 1.6,
         'criteria': [
            {              'description': 'Implement software designs using classes, objects, and inheritance',
               'max_marks': 5
            },          {              'description': 'Apply design patterns and software engineering principles to develop maintainable code',
               'max_marks': 6
            },          {              'description': 'Apply design patterns and software engineering principles to develop maintainable code',
               'max_marks': 5           }         ]      },   }}
```

2.5 ESAM Inference Engine

Backward Chaining is a type of reasoning that starts with the desired goal and works backwards through rules to establish known facts that support the goal. The goal is then divided into sub-goals to verify the accuracy of the facts, following a goal-driven approach where a list of goals determines which rules to use. For proof, backward chaining typically employs a depth-first search strategy [18]. Forward Chaining is a bottom-up approach, where the algorithm begins with the initial state and advances towards the goal state by drawing conclusions from the available facts or data. The Forward-chaining approach is also known as data-driven as it reaches the goal by utilizing available data [19].

ESAM uses Forward chaining as shown in the Fig. 3, it is a reasoning technique that starts with the available data and uses a set of inference rules to derive new facts or conclusions.

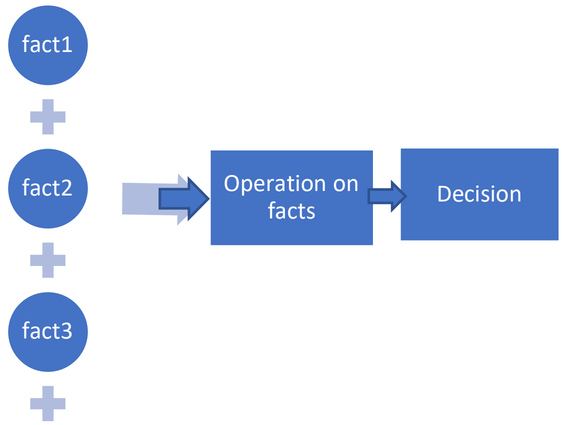

Fig. 3. Forward chaining

ESAM algorithm starts with the assessment scores and uses the knowledge base to infer whether each CLO has been achieved. It iterates through each CLO in the knowledge base and checks if the achieved marks for the corresponding criteria meet the required weightage for that CLO. If the achieved marks meet the required weightage, the algorithm concludes that the CLO has been achieved and adds it to the clo_achievements dictionary. The following ESAM algorithm:

1. Initialize "clo_achievements" dictionary.
2. Loop through each CLO in the knowledge_base['clos'] dictionary.
3. Calculate the total marks for the current CLO.
4. Calculate the achieved marks for the current CLO .
5. Calculate the minimum marks required to achieve the current CLO .
6. Check if the achieved marks for the current CLO is greater than or equal to the minimum marks required to achieve the CLO.
7. If the condition in step 6 is true, add the CLO and description to the "clo_achievements" dictionary.
8. Return the "clo_achievements" dictionary containing all the CLOs achieved by the course assessment.

The following example of the rules to determine the achievement of each CLO:

Rule 1: To achieve CLO1, the student needs to score at least (8 + 4 + 10) = 22 marks in the assessment criteria for CLO1.

Rule 2: To achieve CLO2, the student needs to score at least (5 + 6 + 5) = 16 marks in the assessment criteria for CLO2.
Rule 3: To achieve CLO3, the student needs to score at least (7 + 8 + 5 + 8.4) = 28.4 marks in the assessment criteria for CLO3.

Using these rules, the following function takes the student's scores in the assessment criteria and returns the CLOs that the student has achieved.

```
def infer_clo_achievements(assessment_scores):
clo_achievements = {}
for clo_id, clo_info in knowledge_base['clos'].items():
total_marks = sum([c['max_marks'] for c in clo_info['criteria']])
achieved_marks = sum([assessment_scores[criteria_id] for criteria_id in
clo_info['criteria']])
if achieved_marks >= (clo_info['weight'] / 100) * total_marks:
clo_achievements[clo_id] = clo_info['description']
 return clo_achievements
```

This function takes the assessment scores to calculate the total marks and achieved marks for each CLO based on the assessment criteria and checks whether the student has achieved the CLO based on the ESAM rules.

3. Result and Discussion

COMPUTER PROGRAMMING course is taken as an example to assess the direct assessment of students' performance in the specific course. The following charts of CLOs weight in the COMPUTER PROGRAMMING course and CLO target score are used by ESAM as shown in the Fig. 4:

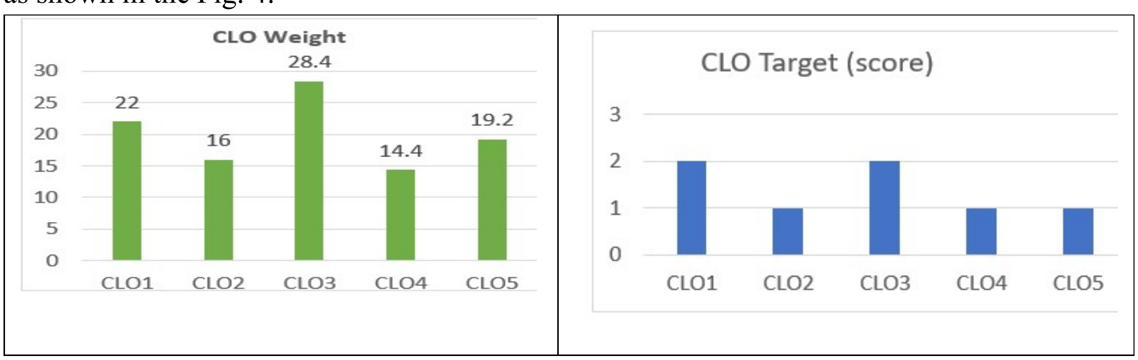

Fig. 4. CLOs Weight and Target

Assessment plan of this course is defined by ESAM as shown in the Table 3.

Table 3. Assessment plan of COMPUTER PROGRAMMING Course

Assessments	Weight as syllabus	CLO1	CLO2	CLO3	CLO4	CLO5
Assignment	20	8	5	7		
Project	30	4	6	8	6	6

Midterm	20	10	5	5		
Final Exam	30			8.4	8.4	13.2
Total Marks/ Weight	100	22	16	28.4	14.4	19.2

The above table represents an assessment plan for COMPUTER PROGRAMMING course with five Course Learning Outcomes (CLOs). The assessment plan consists of four types of assessments: Assignments, Projects, Midterm Exam, and Final Exam. Each assessment type has a different weight as indicated in the "Weight as syllabus" column. The total weight of all assessments is 100. The table shows the distribution of marks for each assessment type across the five CLOs. For example, the assignment has a weight of 20, and 8 marks are allocated to CLO1, 5 marks to CLO2, and 7 marks to CLO3. The table provides a breakdown of the marks for each CLO, allowing for the evaluation of the students' performance on each CLO separately. The table also shows the total marks in each CLO. The total marks for each CLO are calculated by adding the marks obtained in each assessment type for that CLO. For example, the total marks obtained for CLO1 are 22, which is the sum of marks obtained in the Assignment, Project, and Midterm assessments. The overall total marks obtained are calculated by adding the total marks obtained for all CLOs.

The assessment plan is a useful tool for evaluating students' performance and ensuring that they achieve the learning outcomes of the course. It also provides a framework for teachers to design assessments that are aligned with the CLOs and distribute the assessment weight appropriately. This helps to ensure that the assessment plan is fair and accurate in evaluating the students' performance.

Student scores in each CLO is resulted and CLOs achievements by the course assessment are generated by ESAM as shown in the Table 4. This table appears the results of a group of students on five different course learning outcomes (CLOs), as indicated by the CLO1-CLO5 columns. Each student has been assigned a number, and their scores on each CLO are listed in the corresponding row.

Table 4. Student Score and Achievements

Student Number	CLO1	CLO2	CLO3	CLO4	CLO5
1	4	4	1	5	2
2	1	4	1	3	5
3	1	5	3	3	5
4	1	5	3	5	3
5	2	4	3	5	3
6	1	5	5	5	5
7	2	1	5	5	5
8	2	5	5	5	5
9	2	5	5	5	5
10	2	5	1	5	5
11	2	3	5	1	5
12	5	3	5	5	2

Student score

Student Number	CLO1	CLO2	CLO3	CLO4	CLO5
1	81.81	81.25	59.50	100	67.70
2	10.90	87.5	49.29	72.22	100
3	20	100	71.83	72.22	100
4	20	100	75.35	100	79.16
5	60.90	81.25	78.874	100	79.16
6	14.54	100	100	100	100
7	63.634	38.75	100	100	100
8	63.63	100	96.47	100	100
9	63.63	100	100	100	100
10	63.63	100	43.66	100	100
11	63.63	75	100	31.25	100
12	100	75	100	100	65.625

CLOs achievements

Student attainment in each CLO is resulted by ESAM based on what population of students' scores above the target mark 70% for direct assessment. Table. 5 shows the CLOs attainment in COMPUTER PROGRAMMING course. ESAM results are Average marks in each CLO, Students' CLO Status, CLO Target, Score Ave, CLO scale target, Target of the percentage of student numbers, and Percentage of CLO Attainment. The overall result showed that CLO2, CLO3, CLO4, and CLO5 of COMPUTER PROGRAMMING course were achieved and failed to achieve CLO1.

Table 5. ESAM Report

Score	**5**	**4**	**3**	**2**	**1**
CLO1	1	1	0	6	4
CLO2	6	3	2	0	1
CLO3	6	0	3	0	3
CLO4	9	0	2	0	1
CLO5	8	0	2	2	0

CLO attainment

CLOs	CLO1	CLO2	CLO3	CLO4	CLO5
Average	52.196	86.5625	81.25	89.6412	90.9722
Status	Unachieved	Achieved	Achieved	Achieved	Achieved
CLO Target	60	70	60	70	60
Score Ave	2.60984	4.3281	4.062	4.4820	4.54861
CLO Scale Target	2	1	2	1	2
%no.stu target	70	70	70	70	70
%CLO Attainment	66.666	100	75	100	100

Students' achievements and attainment

The above report shows the following:

- CLO1 has an average score of 52.196, which is below the target of 60. This CLO is considered "Unachieved" based on the given status. The average score corresponds to a CLO scale target of 2, and 66.666% of the students have achieved the target.
- CLO2 has an average score of 86.5625, which is above the target of 70. This CLO is considered "Achieved" based on the given status. The average score corresponds to a CLO scale target of 1, and 100% of the students have achieved the target.
- CLO3 has an average score of 81.25, which is above the target of 60. This CLO is considered "Achieved" based on the given status. The average score corresponds to a CLO scale target of 2, and 75% of the students have achieved the target.
- CLO4 has an average score of 89.6412, which is above the target of 70. This CLO is considered "Achieved" based on the given status. The average score corresponds to a CLO scale target of 1, and 100% of the students have achieved the target.
- CLO5 has an average score of 90.9722, which is above the target of 60. This CLO is considered "Achieved" based on the given status. The average score corresponds to a CLO scale target of 2, and 100% of the students
- have achieved the target.

ESAM reports that CLOs 2, 3, 4, and 5 have been achieved by all students for COMPUTER PROGRAMMING course, while CLO1 has been achieved by only 66.666% of the students. The scores for each CLO have been converted to a scale of 1 or 2 based on their target, and the percentage of students achieving each target has been calculated. The target percentage for all CLOs is set at 70%.

Here's an example of how ESAM might work in practice:

1- Upload the student marks in a course:

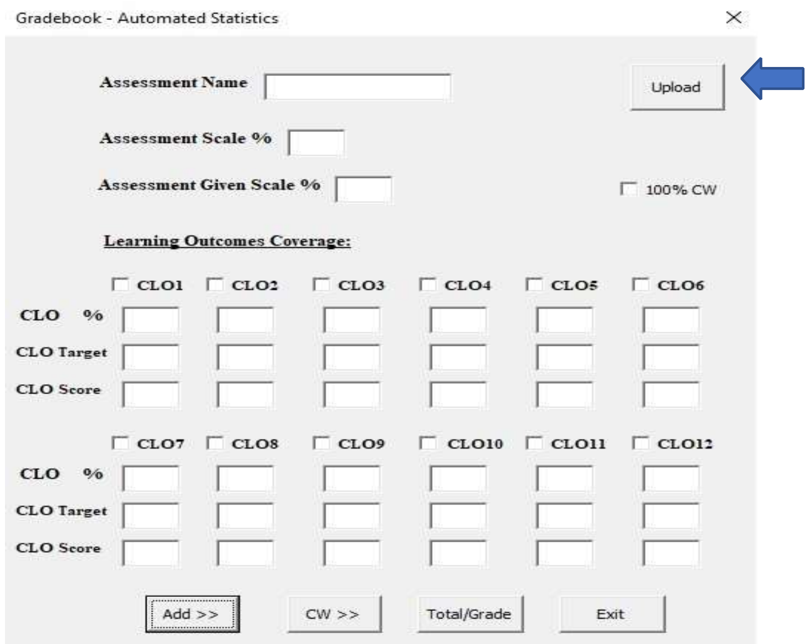

Fig. 5. Upload the student marks in a course.

2- Enter the number of the students:

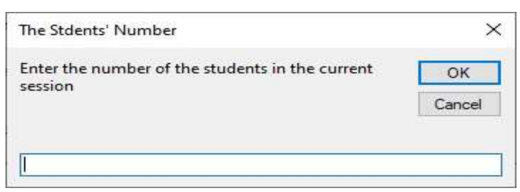

Fig. 6. Enter the number of the students.

3- Enter each assessment separately into ESAM, the following information will be provided:

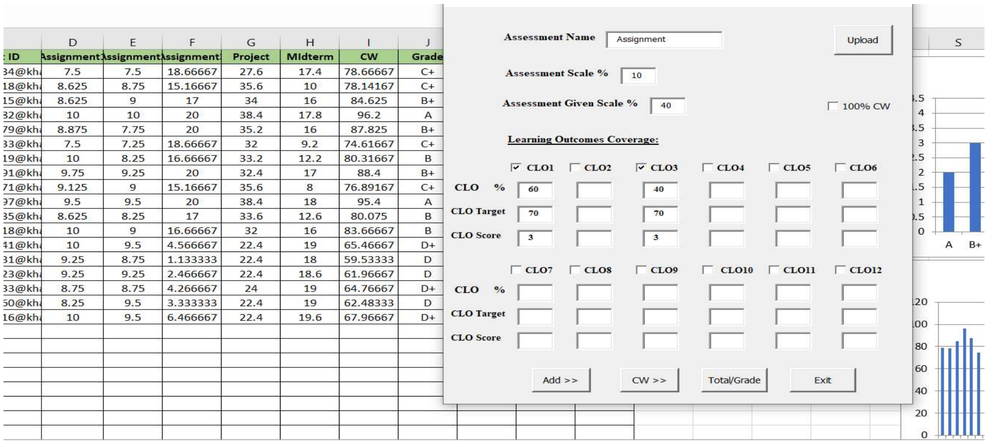

Fig. 7. Enter each assessment details.

a) Assessment name: The name or title of the assessment.
b) Assessment mark as per the syllabus: The maximum or expected mark for the assessment, as specified in the course syllabus or assessment guidelines.
c) Assessment mark as per the assessment given to the students: The actual mark or score that the student received on the assessment.
d) Ticked the CLOs covered by that assessment: Identify which Course Learning Outcomes (CLOs) are covered by the assessment.
e) The percentage of the CLO covered (taking care of having a total of 100): For each CLO covered by the assessment, calculate the percentage of the CLO that is covered by the assessment.
f) The CLO target percentage: The target percentage for each CLO, as defined by the teacher based on the course syllabus or other criteria.
g) The CLO’s score: Calculate the score for each CLO based on the percentage covered by the assessment and the target percentage.

   By entering this information for each assessment, the student progress is tracked on specific CLOs and identify areas where students may need additional support or instruction.

4- Add other assessments by clicking ***Add*** button.
5- Generate Coursework marks by clicking ***CW*** button: after finishing the coursework entry, and before entering the Final Exam assessment, the CW button should be clicked to generate the coursework marks. For courses without Final Exam after finishing the coursework entry, 100% CW will be ticked and then the ***CW*** button will be clicked.
6- ***Total/Grade*** button will be clicked to generate the grades.
7- ***Exit*** button will be clicked to generate the CLO measurement report .

4. Conclusion

ESAM is an artificial intelligence system that aims to measure the effectiveness of teaching and learning methods by analyzing student performance and presenting their achievements in a particular course. It provides a quantitative analysis of students' achievements in terms of knowledge and skill and monitors their progress towards meeting the course learning outcomes (CLOs). ESAM employs a knowledge base and inference engine to define the CLO targets for each course, based on the course level, CLO weights, and rating scale. It calculates the average of students' achievements by the assessment and provides feedback mechanisms for the lecturer to identify areas for improvement and enhance the learning experience for students. The system uses a set of rules for measuring achievements, including calculating CLO weights, defining maximum marks, determining rating scales, and calculating CLO attainment percentages. By consistently analyzing student performance, ESAM helps to guide the lecturer towards monitoring the performance of the CLO and making improvements to the course material. ESAM is a powerful tool for assessing student learning outcomes and improving the quality of teaching and learning by providing quantitative feedback to guide instructors towards areas for improvement.

5. Competing Interests

All authors declare that they have no conflicts of interest.

6. Funding

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