International Journal of Engineering Education Vol. 38, No. 4, pp. 1159–1178, 2022
Printed in Great Britain

0949-149X/91 $3.00+0.00

Continuous e-Assessment of Student Learning Outcomes in a Multi-Agent Blended Learning System*

SALAH HAMMAMI
College of Computer and Information Sciences, King Saud University, Saudi Arabia. E-mail: shammami@ksu.edu.sa

Continuous e-assessments of Student Learning Outcomes (SLOs) is a central feature of education as it provides accurate and complete status of the students' outcome achievement. However, the exiting continuous e-assessment methods are inherently macroscopic as they do not persuade continuous improvement in SLOs during their study period of each student. In this paper, we propose a Multi-Agent Blended Learning System (MA-BLS) to support Continuous e-Assessment Method (CAM) of SLOs. A fully automated CAM will be presented to enable continuous monitoring and evaluation of the progress of each SLO achievement which is covered in different courses during the entire period of an educational level and thus identify and suggest adaptive actions of improvement. A periodic Cumulative SLO-Transcript-like report (SLO-T) reflecting the progress of students' achievement is generated and delivered to the students accompanying their traditional transcript. This SLO-T will facilitate a microscopic status to learners, educators as well as employers thus enabling focus identifications of the capabilities and improvement opportunities for lifelong skills development. To validate the proposed method, we have conducted an experiment on a representative sample of 40 students representing 53% of a batch for two years of their study period. Both cumulative and perception assessments were conducted on the same sample. Finally, a students' perceptions and opinions collected through survey on self-confidence and motivation has revealed satisfactory results in consistence with the conducted cumulative achievement of their SLOs. This study contributes to advancing the field of technology-enhanced continuous e-assessment method of SLO and enhance teaching, learning process and improve academic programs.

Keywords: continuous e-assessment; students learning outcomes; blended learning; multi-agent; student learning outcome-transcript

1. Introduction

Nowadays, Educational Process are shifting towards a learning outcome based approach. So, all of educational activities must be strongly related to learning outcomes. To ensure that learning outcomes are achieved effectively and successfully the assessment process must be also related with learning outcomes. Outcomes-based assessment has increased its importance recently in high education. At King Saud University (KSU) in Saudia Arabia most of colleges became a member of professional accreditation organizations like the Accreditation Board for Engineering and Technology (ABET) [1] and the Saudia National Education & Training Evaluation Commission [2]. All of them requiring that colleges instate the outcome-based assessment and this will help to guarantee continuous improvement in academic programs. Researchers have made efforts to find an effective methodology for assessment in the e-learning environments. Various techniques have been tested for evaluation in the e-learning environment. According to [3], e-assessment can be viewed from three perspectives. First, evaluating the effectiveness and the productivity of the e-learning system itself. This can be performed through several types of reports obtained from an evaluation tool. Such evaluation tools will improve the e-learning system and its performance and ensure that e-learning system achieves its objectives as desired. Second, content-based evaluation [4]. Here, the evaluation of the students learning outcomes in accordance with e-contents in the e-learning system is measured. This determines the students' attainment of outcomes and modification of the e-content accordingly, to improve the low student achievement. Third, evaluating SLOs [3]. This, places student learning at the forefront of academic planning processes based on the outcomes obtained during the learning period. SLO has three levels and is defined as the knowledge, skills, and attitudes that characterize students who complete an academic program [5]. Designing an e-learning system, which emphasizes mapping e-assessment and SLOs is a growing need tantamount to its architectural and implementation complexities. Currently, the pedagogy is witnessing a fast-paced transition from its traditional teacher-centered learning to student-centered assessment strategy [6], focusing on the attainment of SLOs by learners. Consequently, blended learning emerged as the viable alternative that integrates traditional face-to-face learning and online learning with the potential to ostensibly improve the SLOs. In this context, Blended Learning (BL) is believed to be the most effective method of teaching and learning as compared to the e-learning environment [7]. Studies have proven that BL helps in achieving learning

* Accepted 7 June 2022.

outcomes better. BL is completely dependent on the use of technology in traditional face-to-face physical classrooms learning. However, the concept of BL differs from one institution to another on the parameters of technology used in teaching and learning and system objectives [8]. Thus, there are three common aspects for BL definitions. It is a mixed of media transformation of instructional methods. Second aspect is the mix of different pedagogical methods or approaches to obtain the better learning outcomes with or without technology. Thirdly, an integration of any form of traditional face-to-face classroom or meeting (work individuals or teamwork in class meeting) and online learning through an-learning platform [9, 10]. BL proves to be more flexible for students and instructors and augments reflection, autonomy, and research skills and considerably reduces withdrawal rate of students. Moreover, BL can enhance learning environment to be more professional and reduces the overheads of cost and resources [11]. The application of the BL is subjected to several challenges such as, elevated student expectations that are unrealistic, feeling of isolation, technology constraints of institutions and students, time obligation, course redesign support, difficulties in acquiring for new skills of teaching and use of technology [11]. As the Educational industry is transforming at a rapid speed into 'outcome based' learning focusing on what the students should be able to do, learn, and achieve at the end of curriculum. Usually, learning outcomes are used to interpret what it is expected from students to know, understand, and able to demonstrate upon completion of curriculum [3]. BL and continuous assessment are the basic building blocks of student-centered learning. For example, [12] modified blended approach, with the objective of enhancing direct and affective assessment results in his blended classroom implementation. The continuous assessment is the most commonly used assessment method in learning, which continuously evaluates the student learning achievements during the curriculum. From this perspective, our attention in this paper is to propose a MA-BLS to support a continuous assessment policy and improve the SLOs and augment their learning abilities and skills. In this work, we proposed a new CAM based on SLOs and MA-BLS integrated to achieve this goal. This is mainly done to improve students' learning outcomes.

The remaining work is organized as follow: In section 2, the previous and related study are presented. In section 3, we propose the architecture of the MA-BLS. In section 4, we describe the CAM. In section 5, we present a case study to evaluate our CAM and we discuss the significance of what was presented. In section 6, we provide a comparative study with the previous work. In section 7, we discuss the limitations of our work. The last section is dedicated to a conclusion and future research perspectives.

2. Related Works

E-Learning assessment entails several systems implemented for students, teachers, and institutions to track students' performance. Several new learning technologies improved previous systems. These systems are acting as a better assessor than human beings. This literature review gives a comprehensive overview of the most recent topics about the continuous e-assessment to improve student-learning outcomes. Continuous e-assessment systems play a critical role in student performance improvement as it caters more to the student than traditional forms of assessment delivery. Many research studies focused on enhancing the SLOs using several systems and tools in terms of delivering continuous e-assessments. The learning outcome is a projected change in a person's cognitive behavior in addressing a situation, due to the experience and knowledge gained in pursuing the outcome [13]. Attainment of learning outcome determines the level of capability of the learner, assumed to be better than before (before attaining the outcome) by indulging recursively in the learning process. The enhancement of SLOs is a monumental challenge in blended learning environments. According [14], a blended learning improves SLOs to an extent that improves the student's activity levels. This is achieved through increased interactions between student and instructors while applying integrated formative and summative assessment mechanisms to evaluate SLO.

Several systems have recently developed to assess and improve students' skills and outcomes, such as the system proposed by [15] which is based on a Formative E-assessment Model. This system encompasses a grade book, competencies, progress bar, knowledge assessment, and skill assessment module. It ensures to touch all aspects of learning in our students. This solution allows to the student to have an unlimited number of attempts and time to practice each test to improve their skills. Also, students will have feedback in the cases of being successful and being unsuccessful. In case of unsuccessful, based on the feedback, students are directed to the revision module. [16] proposed a general and standardized design for an e-assessment system which supports the formative assessment model that including simple types of questions and provides an interactive dynamic environment for both knowledge and skill assessment through online

education. Furthermore, the effect of formative e-assessments in computer engineering education field to support and improve the students' learning processes. The evaluation of the proposed system performed in a fully online university and it focused on the Logic course of the Computer Engineering degree. Result of proposed formative e-assessment had supported the learning process therefore the students' performances had improved. Furthermore, it helped teachers in order to track the students' learning process. Overall, it had a positive effect on the students' performance and learning procedures. [17] examined the status of the implementation of continuous assessment in Mettu University, Ethiopia. Continuous Assessment (CA) defined as the periodic and systematic method of evaluating and assessing a learner's attributes. The main target of the study is to examine the practice of CA and to determine implementation status of CA in higher education by applying a random stratified sampling method that used to select 309 students and 29 instructors. There are four elements used for data collection: questionnaires, focus group discussion, documents and interviews. First, data entry after data collection process the questionnaire checked for completeness before data entry procedure. Second, data analysis and interpretation, quantitative data were analyzed using descriptive statistical tools such as percentage and frequency. In addition, qualitative data can be described through conceptualization and explanation. The study faced some of challenges such as the Instructors were not considered CA as a part of their job, and produced many of possible solution in order to develop CA assessment. [18] defined a continuous evaluation tool for deeper learning to find a way that makes students work continuously during the course and support high quality in learning for both teachers and students. The continuous assessment is based on three case studies where the main material consists of teachers' experiences and student feedback. The first case is a mandatory 2nd year bachelor level course with 200 students, where students have the ability of choosing continuous assessment or other. Result according to this case was detecting the power of learning assignments over the traditional exams. The second case is a 1st year bachelor level course with number of 130 students, where all students must take individual theoretical assignments and group lab assignments. After this course many students provided their feedback that prefer the traditional exam over the continuous assignments. The third case is a master level course with 60 students. Where students can take ten weekly assignments and feedback of their learning process. This is helping the master students to choose their topics for research and deep learning. Based on the study, continuous assessments guided the students to support their activities in deeper learning. Developing the right content to collect the appropriate information leads to improve student skills. The integration of adaptive learning methods like questionnaires and interviews before creating the system should be made mandatory. [19] proposed an Adaptive Smart Student Assessment (ASSA) model. Such systems include adaptive smart student assessment models where instructors can create contents that directly relate to students. Students can take the test online. That is the system that can determine students' preferred learning styles, skills, and abilities with more accuracy. After that, the system can generate appropriate content and questions to create a learning style. Content creation assessment is done by both the design and the tutor, who determines what is right to deliver to the students after assessing their skills and other attributes. [20] proposed a general system to adapt any component of the assessment process that may include model, activity, question and others based on different evidences that gathered from the learning process from the perspective of learner. The proposed system is called Adaptive Assessment System (AAS). AAS composed of three aspects. First aspect is the evidential module that focused on analyzing the gathered evidences and detecting which evidences are relevant to update the learner/student profile. Second aspect is the adaptive module that responsible for adapting the following assessment activity of the learner. Third aspect is the evidences. There are four different evidences: (i) Learner's performance which expressed the scores of the continuous assessment and the final project; (ii) Number of exercises done by learner; (iii) Presence of the learner in the course; iv) Plagiarism detection for authorship among learners on assessment activities submission. At end, AAS produced the learner's selective score (SC) which is composed of the evidences. Based on the SC degree, the system is determined the final exam or the validation activity to be done by learner. Furthermore, there are three major objectives of AAS. Knowledge and competences acquisition, which considered as the main objective of the system. Also, trust assurance, which is the learner's assessment procedure based on a high level of trustworthiness that can be adapted for high flexibility. Finally, the security assurance, is responsible for validating the assessment performed by learner that has conducted with no infraction. [21] demonstrated that the Individual student success is affected by the educational environment and student characteristics. Educational environment such as continuous assessment to improve students' performance. It produced a questionnaire that

aimed to examine the relationship of different types of continuous assessment and student properties with academic achievement. Where the questionnaire was conducted during the academic year 2014–2015 at the undergraduate law school of Research University in the Netherlands. This survey focused on two main research questions. The first was to what extent the continuous assessment type belongs to academic achievement. The second investigated the major role of the four-student characteristics gender, high school grade point average (GPA), motivation and self-regulation. Results of the questionnaire indicate that continuous assessment provides improvement in student success of male students more than that of female students, but with no preference for male only. Assignments and homework may be negatively affecting students' motivation and self- regulation. Student success in continuous assessment influenced highly by high school GPA of student. [22] studied the different assessment strategies and their effect to students' learning and performance. The objectives of this study are to explore and highlight the effect of continuous assessment strategies for English language studies and defined the views of the faculty regarding the academic performance of students. Furthermore, data was collected in qualitatively and quantitatively manners using questionnaires and students' academic. [23] defined a paradigm by applying methods based on continuous feedback to improve the knowledge and skills acquired by students. This model was based on the "pre-test" and "post-test" strategies, which can detect students' academic performance and immediately provide feedback to students, thereby facilitating the learning process. They mentioned the importance of feedback to students, which can enhance the education of students and make the learning process easier due to the cooperation and feedback between teachers and students. This study presented a suggested model that used feedback as a means of promoting education and provided students with important skills and knowledge that increase their educational attainment in the future. [24] presented a continuous assessment methodology for a computer programming course with used an automatic assessment tool, applied to practical programming exercises that performed by the students. This solution used the e-assessment tool (DomJudge) on the practical part of the course data structure over three terms. DomJudge was an online judge that allowed students to submit their own program solutions, which can be automatically assessed and gave immediate feedback to students. The assessment tool helped students to continuously evaluated programming skills. [25] proposed an e-assessment system to help the student, teacher, institution, and education aim. The student, using this system, was able to take the test or assignment at any time and any place, which provides flexibility for students. In terms of teachers, the system helped teachers to improve the quality of feedback and reduced manual correction of test errors. Teachers can be analyzed the response and track the progress of the students that helped discover the parts that the students do not understand. On the other hand, for institutions that should increase the number of students and require quick and accurate assessment so, using electronic assessment can reduce the time and cost. [3] presented an adaptive learning system and an Academic Advisor Agent which using continuous assessments to improve deaf student learning outcomes. This system evaluates the Deaf Students Learning Outcomes results (DSLO) by an Academic Advisor Agent. Where, the Academic Advisor objective is to monitor the students' achievements of the learning process and to support them with advices to better satisfy the program Student Outcomes. The deaf student continuous assessment result (CAR) which denotes the deaf student's score. The proposed CAR assigned an adviser agent that focused on continuously improve the DSLO's of deaf students by measuring their achievement periodically at the end of predefined terms. By monitoring the learner achievements and providing feedback and advices to the learner to better achieve results.

3. Student Learning Outcomes and Blended Learning System

3.1 Student Learning Outcomes

Continuous assessment is used to evaluate students learning by different assessments such as daily class work, course related projects, papers and practical work. This provides the students several opportunities to improve the subject knowledge mastery and hone the skills through increasing self-awareness, comprehending the knowledge and proficiencies. This section describes in detail our proposed algorithm used to assess SLOs. In addition, it provides success levels suggested for student achievements. These levels allow the instructor to decide on the type of support activity that needs to dispense to improve the student's attainment and tracking the improvement. The SLOs defined as student's skills and abilities that a student should acquire in an enrolled curriculum. These skills and abilities could contain a set of personal development skills such as problem solving and/or domain-specific technical skills [3]. The SLO is achieved by fulfilling the related course learning outcomes. An SLO can be scattered over one or more different courses and their learning outcomes to be achieved

in curriculum. The weight of one learning outcome is determined by curriculum experts. Generally, the weight varies from one course to another. Fig. 1 shows the relation of SLO with targeted courses. The progress of every SLO is characterized by Course Learning Outcome (CLO) attainment in a specific course. Traditionally, SLO achievement is measured by student's success at the end of period (semester) for different courses contributing to the SLO. In essence, a student may pass the course but may still be lagging in some skills or topics of that passed course. SLO assessment method is a continuous approach used to monitor student's achievements in a specific SLO. It aims to address the weakness found at the end of every period, by providing alternative activities for this weak achievement. We use MA-BLS to optimize the achievement of learning objectives by applying the right learning technologies, to match the right personal learning style, in order to transfer the right skills to the right person at the right time. In fact, MA-BLS programs are using different learning tools; such as self-paced Web-based courses, real-time virtual/collaboration software, self-paced Web-based courses, electronic performance support systems embedded within the job-task environment and learning management systems. Further, it supports live e-learning, online forums for discussions and online activities involved in the face-to-face learning. Successful MA-BLS reinforces students' achievement to achieve qualitative SLO and ensures satisfaction of students and teacher. Indeed, several core factors pertaining to both students and institutions, have a variable impact on the success of MA-BLS. The most important students' factors considered in MA-BLS development and implementations are; students' needs, their expectations of management, the satisfaction and understanding level of students.

3.2 Architecture of Muli-Agent Blended Learning System

The proposed MA-BLS is developed to achieve the SLOs using a CAM which will be described in next section. There are two types of assessment complementing the proposed blended assessment: (i) face-to-face evaluations process and (ii) online assessment as a support activity delivered to students who reflect weaknesses in their learning outcomes. In this section, we will describe the architecture of the proposed MA-BLS to support Student Learning Outcomes. This system (Fig. 1) analyzes the students' evaluation results obtained from face-to-face learning in online system.

Also, it uses a continuous assessment approach to make recommendations to improve student learning outcomes. In MA-BLS, the instructor feeds the face-to-face evaluation results to the online system. The online system analyses these results and fetches the related student profile form SLO database. Post the fetch, it recalculates the skills achievements in line with the results to analyze and specify SLO's weakness. After computing the SLO achievement, Assessment Advisor compares

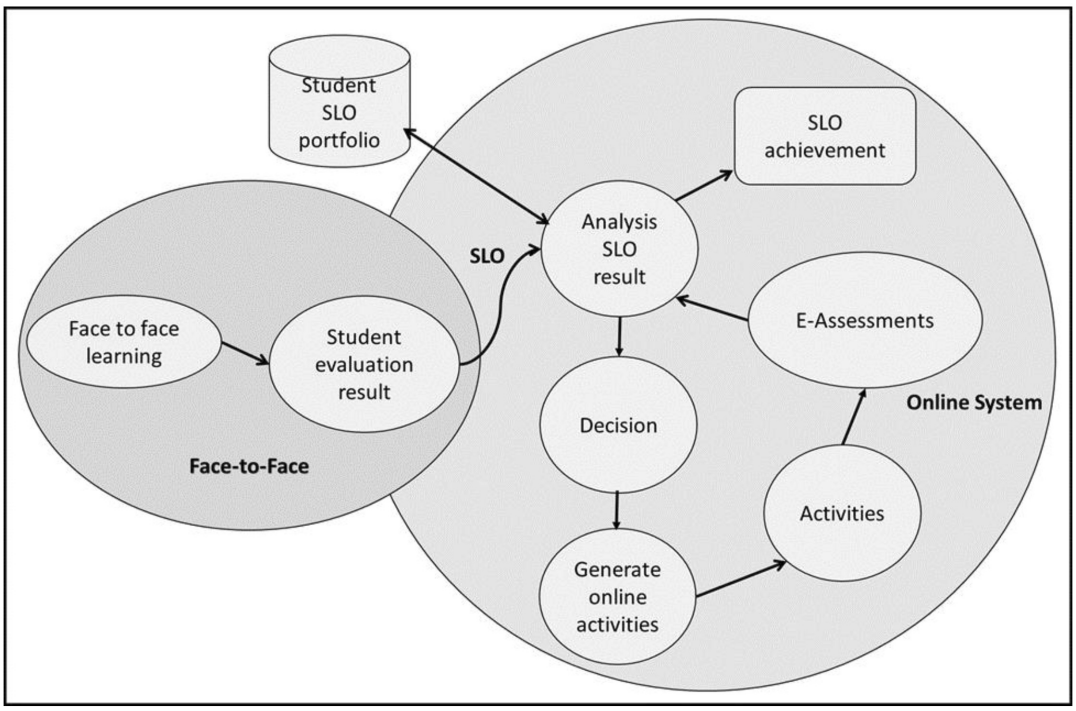

Fig. 1. Overview of MA-BLS.

the calculation results with its threshold to determine if there is a weakness in a specific SLO and decide on an action plan accordingly to the level of their achievement of SLO. If there is no match or the result is less than threshold, Assessment Advisor Agent (AAA) will continue to decide on a weakness level. Later, it analyzes as to which online alternative activities should be delivered to student to enhance his skill failure or weakness. The alternative activity will be laid out as a course path containing sections, tutorials, online exam, exercises, project, or/and alternative course related to this weakness. On successful conclusion of the alternative activity by the student, the results are analyzed again to recalculate SLO achievements. Students can access Student SLO portfolio is a database containing students' records. The portfolio includes student's personal information, registered course, and their related SLOs grades of skills with threshold weights. Fig. 2 reflects the MA-BLS architecture. Mainly, it consists of two sub-systems.

(a) *Face-to-face learning subsystem:* It represents in-class learning with student and evaluations results. The student evaluation results will be fed by the instructor to online assessment platform i.e. second part of the MA-BLS architecture tasked to assess the student learning outcomes' achievement.

(b) *Online Assessment Sub-system:* In the following we are interested, particularly, in the description of the Middle Layer which is divided into two layers: Business Layer and Data Access Layer:
- The business Layer contains Student Agent, Assessment Advisor Agent, and Instructor Agent. *(i)* Student agent is responsible for all functions related to the student. It communicates with AAA to initialize student learning outcomes and student learning portfolio in data access layer. Student agent participates with AAA to monitor student progress in SLOs achievements and assessment activities. *(ii)* AAA is a super system agent that manage all learning environment and control communication between all system agents, it acts as system administrator. Fig. 3 shows AAA components which are Model, View and Controller. View is an interface of agent used to insert, update and delete its behavior. Controller is used to control communications and controlling data follow between AAA and other agents. Model component is used to implement all agent's functionality. Also, it is responsible to determine the SLO's weights with success threshold level according learning program, helps student agent to create and initializes student portfolio with related student learning outcomes. This

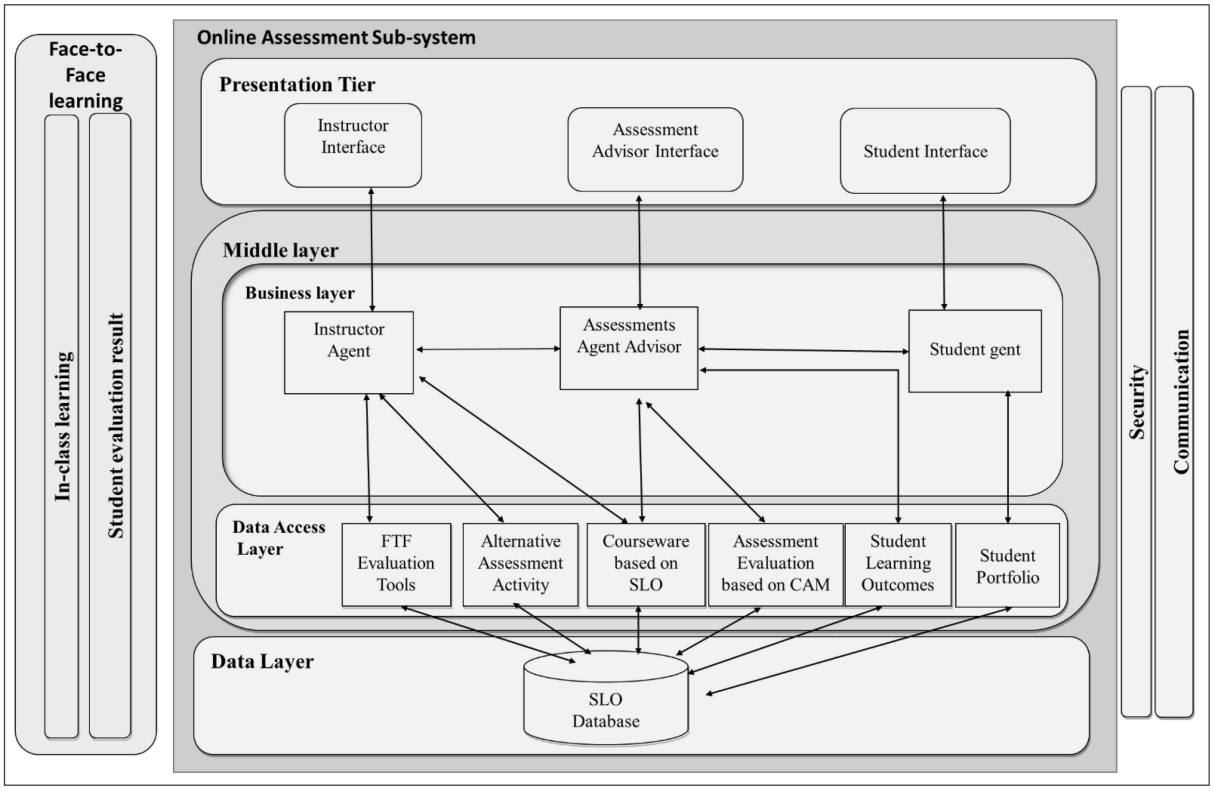

Fig. 2. MA-BLS Architecture.

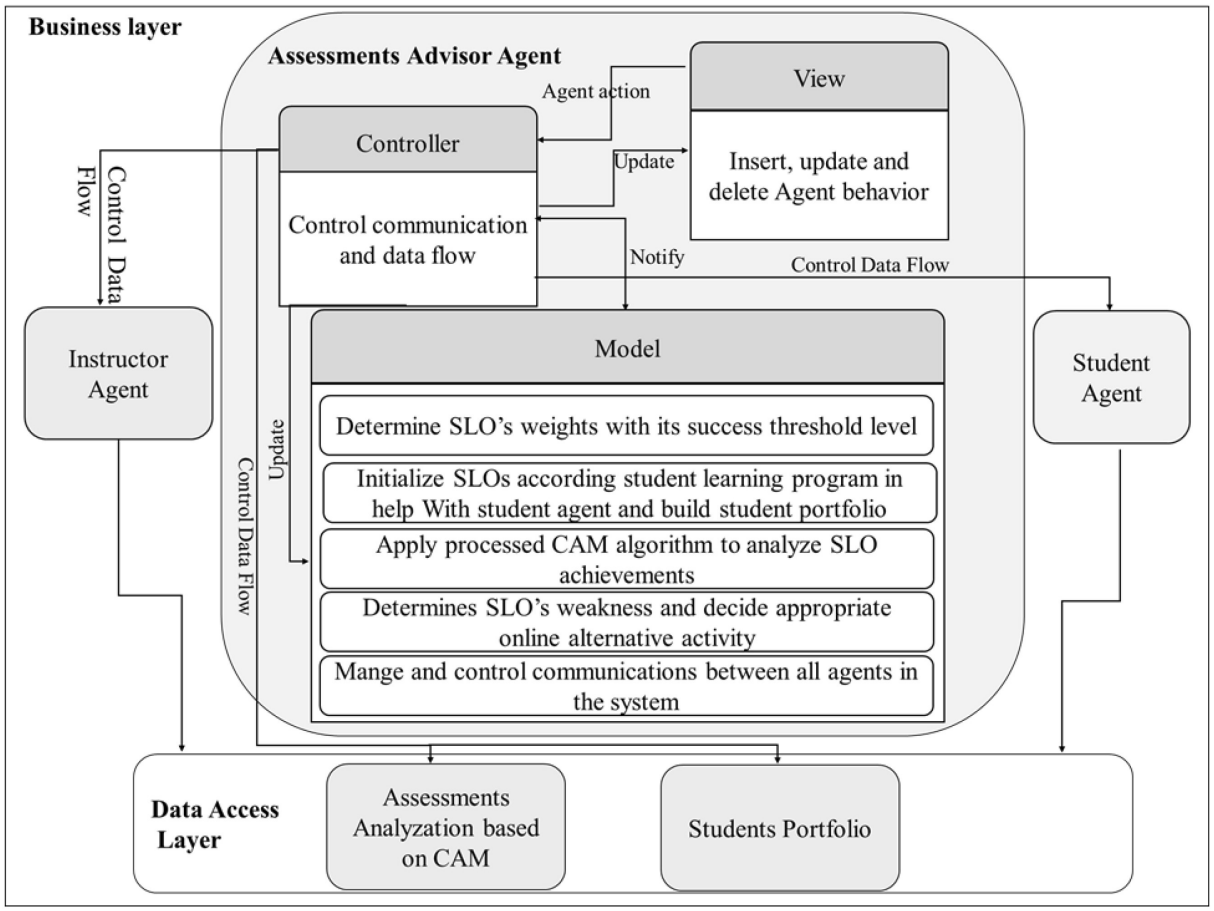

Fig. 3. Assessment Advisor Agent structure model.

agent responsible for applying and implementing proposed CAM algorithm to assess student achievements in his learning outcomes. In addition, if student have weakness according to CAM algorithm in specific SLO achievement, AAA decides the appropriate online alternative activity and request Instructor agent to create it. *(iii)* Instructor Agent (IA) is composed of three agents: Course Generator Agent (CGA), Course Assessment Agent (CAA) and Alternative Agent (AA). CGA enables the instructor to access system recourse and provides him with information about learning environments and helps him to produce learning object with contents that contribute to student learning outcomes. CCA provides instructor to create different assessment tools for courses in order to evaluate students learning outcomes achievements in specific SLO. AA offers tools to the instructor so that can create alternative assessment activity and alternative learning object to address student weakness in a particular SLO achievements.

- Data access layer: is used for database connection and created by Entity Framework [26]. It contains FTF evaluation tools, alternative assessment activity, courseware based on SLO, assessment analysis based on CAM, student learning outcomes and student portfolio.

4. Continuous e-Assessment Method

A new CAM will be used to monitor students' outcomes achievements in each assessment type and not for their overall course grades. CAM will be applied during course evaluation and at the end of course. Fig. 4 describes the SLO according to the curriculum. There are different courses sharing the same SLO_y with different weights α_x in every related courses C_x in various periods during curriculum. The total weight for every SLO_y along curriculum is 1. Every enrolled course has different assessment types (k assessment types, from e_1 to e_k such as quiz, homework, midterm, etc.). All e_k types will share the given weight $\alpha_{x,k}$ of SLO_y in the course which specified by the course instructor.

In the proposed CAM, according to assessment threshold, if the student has weak achievement as

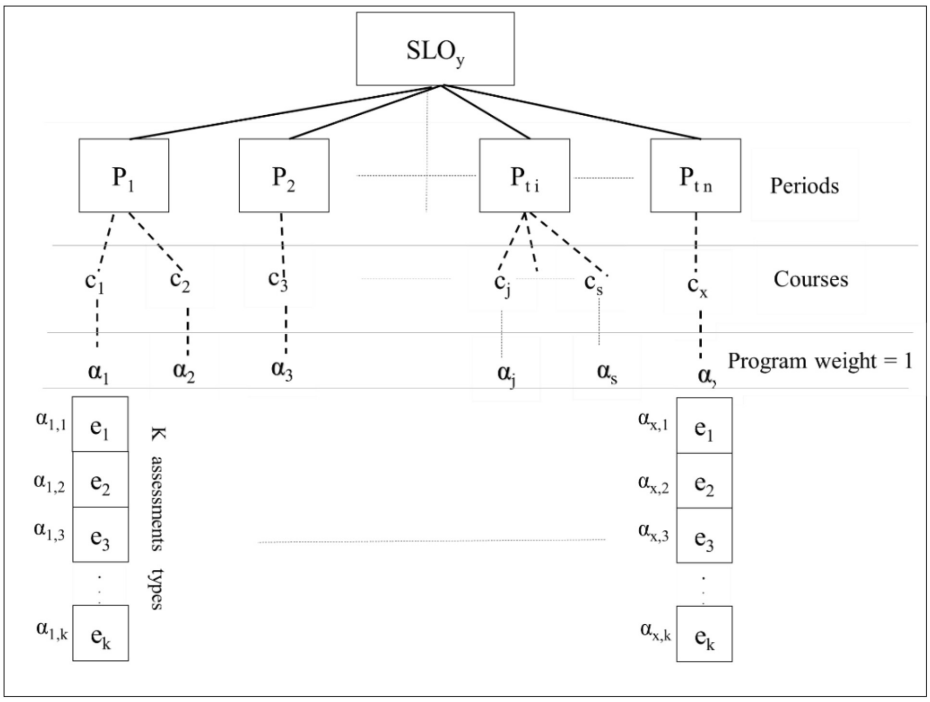

Fig. 4. Student learning outcome (SLO).

specified by a course evaluation tool, the student is liable to a corrective chance/s i to improve or address his weakness during specific correcting period. The correction period for the student is generally determined by instructor or automatically end with next assessment e_{k+1}. In case the student did not reflect a better achievement, post availing the corrective chance, the achievement from corrective chance will not be taken into consideration for the overall evaluation. The student's acquirement with all corrective chances in e_k for specific SLO_y in related course C_x will be represented as $SA_{x,y,ek}$ and calculated by Equation 1:

$$\boldsymbol{SA_{x,y,e_k}} = \sum_{i=1}^{n} (\boldsymbol{m_{k,i}}) \tag{1}$$

Where $m_{k,i}$ is the mark achieved in e_k according to the weight of SLO_y $\alpha_{x,k}$, which will be calculated by Equation 2; and n is the number of corrective chances that granted to student as alternative activity when he has a weakness in order to enhance his achievement in e_k. If the student satisfies the threshold at the first work of e_k, the $SA_{x,y,e_k} = m_{k,1}$. Where A_{x,y,e_k} is the student's achievement of e_k assessment type of specific SLO_y in related course C_x, $\alpha_{x,k}$ is the weight of SLO_y in e_k of course C_x, and eMark is the total mark of e_k.

$$\boldsymbol{m_{k,i}} = \frac{\boldsymbol{A_{x,y,e_k} \times \alpha_{x,k}}}{\boldsymbol{eMark_{x,y,e_k}}} \tag{2}$$

The impact factor considers the recent achievement only if it has a higher impact on SLO value than before. The impact factor of student achievements in $eA_{x,y,ek}$ with different corrective chances is the focal point (Fig. 5). It is used to differentiate between student's acquirements in e_k. The success value of SLO's achievement with corrective chance/s is the average of achieved marks using a weighing function. The impact factor will be used in the proposed CAM in a different way.

In CAM, the success chance will have full impact with value 1, but the chance with weak achievement will have a lower impact. For example, if student passed after the third corrective chance in e_2, his acquirement will be $(m_{2,1} + m_{2,2} + m_{2,3})$ using Equation 3, and the number of corrective chances will be calculated by Equation 4 that will be $(\frac{1}{3} + \frac{1}{2} + 1)$ that mean the impact value of $m_{2,1}$ is $\frac{1}{3}$, for $m_{2,2}$ is $\frac{1}{2}$ and for $m_{2,3}$ is 1.

Then the number of chances will be $NC_{x,y,e_2} = 1.83$. The achievements eA_{x,y,e_k} in e_k will calculated by the Equation 5.

$$\boldsymbol{\varphi(i,n)} = \frac{1}{n-i+1} \tag{3}$$

$$\boldsymbol{NC_{x,y,e_k}} = \sum_{i=1}^{n} \varphi(i,n) \tag{4}$$

$$\boldsymbol{eA_{x,y,e_k}} = \left(\frac{\sum_{i=1}^{n} (\boldsymbol{m_{k,i}})}{\sum_{i=1}^{n} \boldsymbol{\varphi(i,n)}}\right) \tag{5}$$

Equation 5 can be written as:

$$\boldsymbol{eA_{x,y,e_k}} = \left(\frac{\boldsymbol{SA_{x,y,e_k}}}{\boldsymbol{NC_{x,y,e_k}}}\right) \tag{6}$$

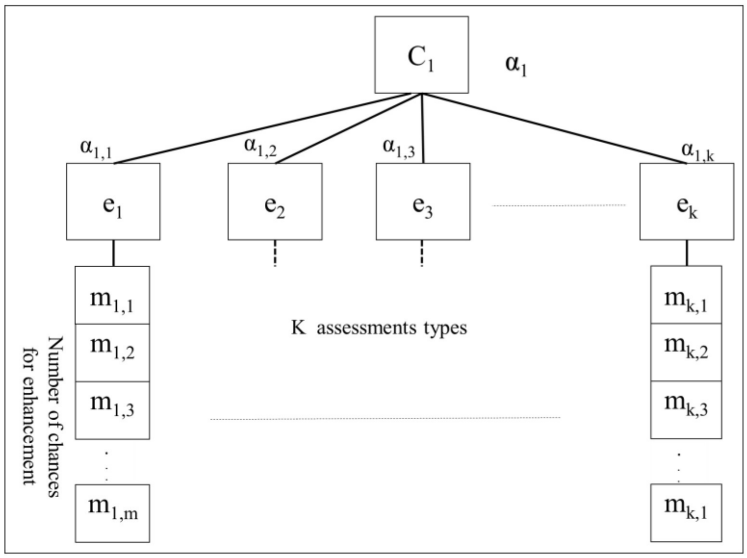

Fig. 5. Corrective chances for every K assessment types.

At the end of period t_p (course tenure-semester) the student's achievements in C_x for all assessment types e_k (denoted as $CA_{x,y,tp}$) can be calculated by Equation 7:

$$\boldsymbol{CA_{x,y,t_p}} = \frac{\boldsymbol{100}}{\boldsymbol{\alpha_x}} \sum_{\boldsymbol{j=1}}^{\boldsymbol{k}} \boldsymbol{eA_{x,y,j}} \tag{7}$$

Where k is the number of assessment types in course C_X. All these courses will be considered as one course contributing to one course outcome ($CO_{y,tp}$) with one *SLO*'s weight $\beta_{y,tp}$, which is the summation of weight α_x for every related Course C_x at the period (t_p) as shown in Equation 8 and 9.

$$\boldsymbol{CO_y, t_p} = \sum_{\boldsymbol{c=1}}^{\boldsymbol{s}} (\boldsymbol{CA_{c,y,t_p}} \times \boldsymbol{\alpha_c}) \tag{8}$$

Where s is the number of courses in period t_p.

$$\boldsymbol{\beta_{y,t_p}} = \sum_{\boldsymbol{c=1}}^{\boldsymbol{s}} (\boldsymbol{\alpha_c}) \tag{9}$$

We can calculate the student leaning outcomes (SLO_y) achievement at period t_p using Equation 10:

$$\boldsymbol{SLO_{y,t_p}} = \left(\frac{\boldsymbol{CO_{y,t_p}}}{\boldsymbol{\beta_{y,t_p}}}\right) \tag{10}$$

Also, in CAM, we can calculate the history of SLO achievement at current period t_p for specific SLO_y that depends on the total weights of achieved outcome. It denoted as a cumulative learning outcomes (cmO_{y,t_p}) and calculated using Equation 11:

$$\boldsymbol{cmO_{y,t_p}} = \begin{cases} \boldsymbol{SLO_{y,1}} & , \quad \boldsymbol{p = 1} \\ \frac{\sum_{\boldsymbol{r=1}}^{\boldsymbol{p}} (\boldsymbol{SLO_{y,r}} \times \boldsymbol{\beta_{y,r}})}{\sum_{\boldsymbol{r=1}}^{\boldsymbol{p}} (\boldsymbol{\beta_{y,r}})}, & \boldsymbol{p > 1} \end{cases} \tag{11}$$

Where p is the current period which will be calculated with the previous history from 1– to – p1.

The proposed CAM has two levels of threshold to decide a weakness to take a corrective action (or alternative activity). These are a course evaluation level during course evaluation process and learning object level at the end of course evaluation period:

- *SLO evaluation threshold*
  - Meeting expectation (ME) threshold: In this level the student is required to achieve and must satisfy the ME threshold. ME is determined by the following function and compared with student achievement in e_k, $eA_{x,y,e_k} \geq ME_{e_{x,k}}$

    where $ME_{e_{x,k}} = \left(\frac{\alpha_{x,k} \times TH_x}{100}\right)$. Where TH_x is the success threshold for specific course C_x which specified by curriculum experts.

  - Does Not Meet Expectations (DNME) when $eA_{x,y,e_k} \leq ME_{e_{x,k}}$: Student has to do alternative activity created to improve the weakness in achievement of outcome.
- *Learning Object Assessment Threshold*

  At the end of period t_p the $SLO_{y,tp}$ is computed as student's learning outcome achievement in all evaluations activities. We determine the mastery level by comparing it with history achievements of SLO_y by using Equation 11. The evaluation of $SLO_{y,tp}$ is considered to be attained, if the student achieved a score of 65% or above in the cumulative achievement. Four levels of satisfaction have been defined (Table 1).

Table 1. Student outcomes attainment at the student's level in continuous e-assessment method

Student's Satisfaction		
Student score in a specific outcome	**Evaluation**	
X < 60 %	DNME	Does Not Meet Expectations
60 % ≤ X < 65 %	PE	Progressing Towards Expectations
65 % ≤ X < 85 %	ME	Meets Expectations
85 ≤ X	EE	Exceeds Expectations

- EE and ME: no Action.
- PE: the instructor has elective action to take as an enhancement program to improve the SLO achievement of the student in next period. This action will be on weak achievement of learning object for specific course in a period tp.
- DNME: the student has to take a compulsory action such as exams, assignments, reading chapter, tutorials, or any action that created by instructor to improve his learning outcomes and address weakness point of course that has low achievement.

5. Evaluation of the Proposed System

In case of our proposed CAM validation, we built a MA-BLS which used to assess SLO based on the CAM Algorithm. It allows instructors to apply continuous assessment. It also lets student access to their registered courses, courses information, evaluation tools used in course, alternative activities built for the weakness improvement, submit solutions and learning outcomes achieved. We chose Microsoft Visual Studio with ASP.NET, MVC design pattern, C# language, SQL Server to build the project's database. CSS, Java and Scripts to build the BAS platform. The MA-BLS was built using 3-tier architecture, multi-agent system and MVC design pattern.

5.1 Method

In fact, in order to prove the applicability of the proposed system, a comparative study was conducted since the first semester of 2019 with 40 students of B.Sc. degree in the Computer Science Department of CCIS-KSU which represents 53% of the batch under focus. They were divided into two groups through convenience sampling. The first group (20 Students) will be assessed using our CAM and the second group (20 Students) will be assessed according to another approach called Continuous Assessment Result (CAR) defined in [3]. According to this case study, we applied CAM and CAR to monitor one SLO from the list of outcomes identified by ABET (SLOa . . . SLOk) and show progress of student achievement in all related courses (C1 . . . C8) during four periods (Table 2): t_1, t_2 , t_3 , t_4. The assessed achievements are intended on the student achievement of the SLO_a ("*an ability to apply knowledge of mathematics, computing, science, and engineering appropriate to the discipline*"). We chose this outcome because it is covered by eight courses.

There are two types of assessment activities in CAM. The first is during course learning within evaluation period delivered to student as corrective chance/s to correct his weakness, and the second is an alternative activity for his weak achievement in

Table 2. Part of Computer Science Courses mapped to student outcomes based on ABET

	Periods							
	P t1		**P t2**			**P t3**	**P t4**	
Course / **SLO**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
SLO_a	X	X	X	X	X	X	X	X
SLO_b			X			X	X	X
SLO_c	X	X	X					X
SLO_d		X						X
SLO_e								
SLO_f								
SLO_g								X
SLO_h								
SLO_i	X	X			X			X
SLO_j					X	X	X	
SLO_k				X				

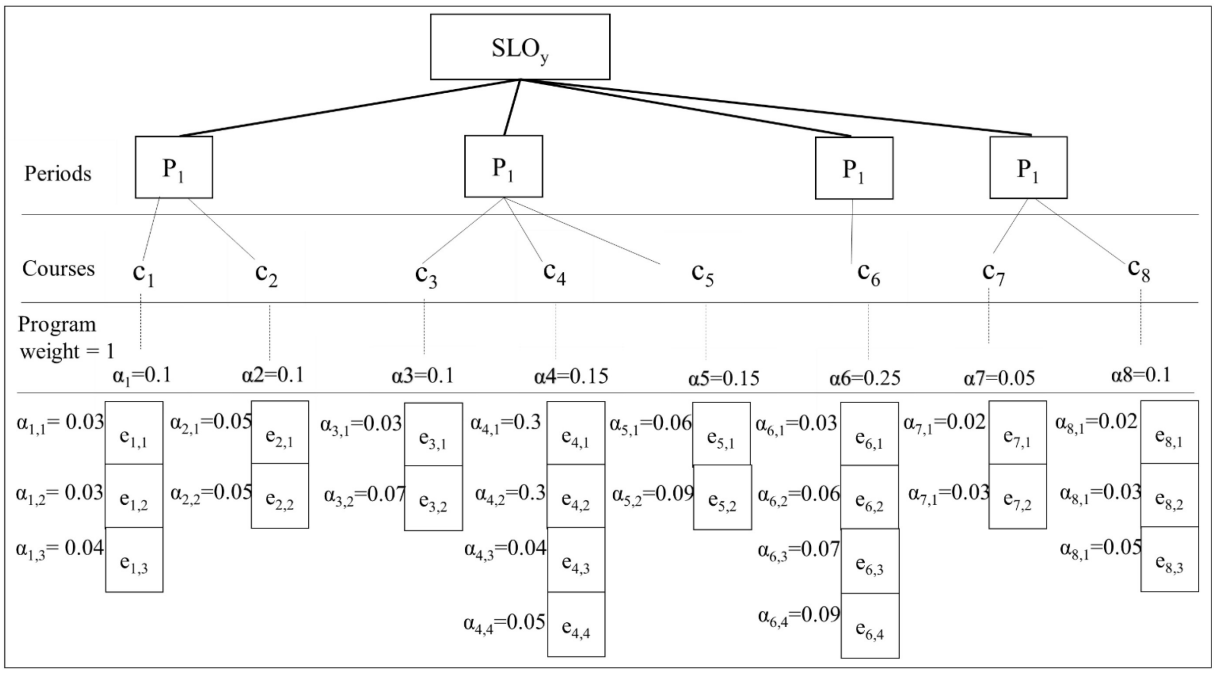

Fig. 6. SLOa shares eight courses through curriculum.

learning object in related course. But in CAR [3] only one alternative activity taken only at the end of period depend on success threshold level based on CAR value of that period. As in Fig. 6, we suppose that the success threshold for all courses is (TH = 60%), and the weights in Fig. 6 will be multiplied by 100 to clarify the calculation process.

5.2 Results

As results of this experience, we have focused on the following aspects:

(a) Comparison between outcomes' achievement of the group who used our CAM with the group who followed another approach called CAR (see Table 3 and 4). An appendix shows a case study of one student results with some of the detailed calculations.
(b) Students' testimonials and perceptions about this continuous e-assessment method (see Table 5) focused on:
   – students' self-confidence: Does the CAM develop and maintain the students' self-confidence to achieve their skills and their ability to carry out a given assessment?
   – students' motivations: Does the CAM offer to the students a challenge to take up their skills or not?.
(c) Teachers' opinion about the applicability of this type e-assessment method.

Table 3 shows the cumulative achievements' of SLOa of the students who followed the CAM method. On the other hand, Table 4 presents the Cumulative Achievements' of SLOa concerning the 20 students who followed the CAR approach. Tables 5 shows the opinion of the students and teachers on the above-mentioned aspects b. They were obtained from surveys.

5.3 Discussion

For every SLO, the instructors provide a CAM report including the SLO-T, and propose corrective actions to improve the student outcome achievement in the following semester. The evaluation is considered to be attained, if the student achieved a score of 65% or above in the cumulative achievement. Four levels of satisfaction have been defined in Table 1. Table 3 and 4 shown the students' performances (CAM group and CAR group) in achieving the SLOa outcome during 4 periods of assessment based on to the scales shown in Table 3.

According to Table 3, we notice that there are two students ($S9_1$ and $S14_1$), which represent 10% of the group, who did not meet expectation by following our approach CAM. According to Table 4, we notice that there are three students ($S3_2$; $S9_2$; $S15_2$), which represent 15% of the group, who did not have good results by following the approach CAR. In conclusion, as it can be seen in Table 3, the Increase Rates (IR) obtained using CAM overtakes those obtained in Table 4 by CAR algorithm. In particular, the (min IR = 6.5%) recorded by CAM is greater than the (max IR = 6.3%) recorded for CAR.

Table 3. Cumulative Achievement satisfaction of SLOa by the students assessed with CAM experience

Student Num	Period t1	Satisfaction	Period t2	Satisfaction	Period t3	Satisfaction	Period t4	Satisfaction	Increase Rate (IR)
$S1_1$	79	ME	82	ME	84	ME	86	EE	**8.9**
$S2_1$	60	PE	63	PE	65	ME	69	ME	**15.0**
$S3_1$	72	ME	75	ME	77	ME	81	ME	**12.5**
$S4_1$	78	ME	81	ME	83	ME	84	ME	**7.7**
$S5_1$	75	ME	73	ME	77	ME	80	ME	**6.7**
$S6_1$	77	ME	78	ME	80	ME	82	ME	**6.5**
$S7_1$	61	PE	64	PE	66	ME	70	ME	**14.8**
$S8_1$	57	DNME	69	ME	62	PE	65	ME	**12.3**
$S9_1$	59	DNME	60	PE	57	DNME	58	DNME	**–1.7**
$S10_1$	80	ME	82	ME	84	ME	87	EE	**8.7**
$S11_1$	72	ME	75	ME	76	ME	78	ME	**8.3**
$S12_1$	76	ME	78	ME	80	ME	85	EE	**11.8**
$S13_1$	70	ME	73	ME	75	ME	79	ME	**12.9**
$S14_1$	58	DNME	61	PE	60	PE	56	DNME	**–3.4**
$S15_1$	65	ME	67	ME	70	ME	74	ME	**13.8**
$S16_1$	59	DNME	62	PE	64	PE	67	ME	**13.6**
$S17_1$	74	ME	76	ME	79	ME	83	ME	**12.2**
$S18_1$	60	PE	63	PE	64	PE	67	ME	**11.7**
$S19_1$	71	ME	75	ME	78	ME	80	ME	**12.7**
$S20_1$	57	DNME	60	PE	62	PE	65	ME	**14.0**

Table 4. Cumulative Achievement of SLOa by the students assessed with CAR experience

Student Num	Period t1	Satisfaction	Period t2	Satisfaction	Period t3	Satisfaction	Period t4	Satisfaction	Increase Rate (IR)
$S1_2$	76	ME	77	ME	79	ME	80	ME	**5.3**
$S2_2$	73	ME	75	ME	76	ME	75	ME	**2.7**
$S3_2$	60	PE	58	DNME	57	DNME	55	DNME	**–8.3**
$S4_2$	65	ME	67	ME	68	ME	69	ME	**6.2**
$S5_2$	71	ME	73	ME	76	ME	75	ME	**5.6**
$S6_2$	58	DNME	60	PE	60	PE	61	PE	**5.2**
$S7_2$	63	PE	64	PE	66	ME	68	ME	**3**
$S8_2$	80	ME	82	ME	84	ME	85	EE	**6.3**
$S9_2$	62	PE	60	PE	57	DNME	58	DNME	**–6.5**
$S10_2$	80	ME	81	ME	83	ME	84	ME	**5**
$S11_2$	78	ME	80	ME	81	ME	82	ME	**5.1**
$S12_2$	63	PE	67	ME	66	ME	67	ME	**6.3**
$S13_2$	78	ME	79	ME	80	ME	82	ME	**5.1**
$S14_2$	62	PE	63	PE	62	PE	65	ME	**4.8**
$S15_2$	59	DNME	60	PE	58	DNME	56	DNME	**–5.1**
$S16_2$	67	ME	65	ME	66	ME	68	ME	**1.5**
$S17_2$	76	ME	77	ME	79	ME	80	ME	**5.3**
$S18_2$	64	PE	63	PE	66	ME	67	ME	**4.7**
$S19_2$	65	ME	75	ME	78	ME	77	ME	**5.5**
$S20_2$	66	ME	60	PE	63	PE	62	PE	**5.1**

To analyze the students' testimonials and perceptions about this CAM, we used the same process that we applied in our ABET accreditation to provide assurance that our college program meets the quality standards of the profession for which that program prepares graduates. Under this, in every course, at the end of the semester, the faculty member applies an indirect assessment. This is mainly used as a supplementary assessment measure as it measures the students' perception concerning the achievements of the relevant student outcomes in his course. The students' perceptions and opinions collected through survey. This indirect assessment does not target the student outcomes

Table 5. Student outcomes attainment at the student's level in Indirect Assessment

Student outcomes attainment scale for a student		
Student score in a specific outcome	**Evaluation**	
"Disagree" + "Strongly Disagree"	DNME	Does Not Meet Expectations
"Neutral"	PE	Progressing Towards Expectations
"Agree"	ME	Meets Expectations
"Strongly Agree"	EE	Exceeds Expectations

Table 6. Opinions of students about self-confidence and motivation

Has the continuous e-assessment method improved your confidence in your own abilities to achieve your skills?					
	Strongly-agree (EE)	Agree (ME)	disagree (PE)	Undecided (DNME)	Strongly-disagree (DNME)
Period t1	**65%**		20%	10%	5%
Period t2	**75%**		10%	10%	5%
Period t3	**80%**		10%	10%	
Period t4	**90%**		5%	5%	
Are you motivated and fulfilled while making new experiences, to achieve your skills by following the new form of assessment?					
	Strongly-agree (EE)	Agree (ME)	disagree (PE)	Undecided (DNME)	Strongly-disagree (DNME)
Period t1	**75%**		15%	5%	5%
Period t2	**85%**		10%	5%	
Period t3	**90%**		5%	5%	
Period t4	**95%**			5%	

but rather assesses the students' global satisfaction with the quality of teaching and they get and their level of satisfaction with all the supporting facilities and the activities. In order to gather students' testimonials and perceptions about the continuous e-assessment method, two questions were included in this indirect assessment. We asked the student to rate how self-confidence and motivation they are that their answer was correct after following the continuous e-assessment method*: (i) Has the continuous e-assessment method improved your confidence in your own abilities to achieve your skills? (ii) Are you motivated and fulfilled while making new experiences, to achieve and enhance your performance by following the new form of assessment?*. These questions were revised by the Assessment Committee whose one of their roles is to analyze survey data and levels recommendations to the Department about the learning outcomes that students feel they did not sufficiently acquire.

We used the typical five-level Likert scale [27] "Strongly-agree", "Agree", "Disagree", "Undecided", and "Strongly-disagree" to assess the students' opinions. Therefore, for our indirect assessment (survey), an outcome or an objective is considered to be attained if the student answer to the corresponding question is "Strongly Agree" or "Agree". Four levels of satisfaction have been defined (Table 5).

Table 6 displays the students' opinion on self-confidence and motivation based on the scale shown on Table 5. The table shows the percentage of students who showed satisfactory level or above in that specific question. As it can be seen, most of the students are satisfied with the continuous e-assessment method. The results regarding students' self-confidence and motivation are highly rated and it's improved each period.

In order to determine the coherence between the students' perception and the cumulative achievement of the outcome using the continuous e-assessment method, a comparison analysis was done between both questions of the survey and the percentage of students who showed satisfactory level or above in that specific outcome. Table 8 shows the improvement of the percentage of students achieving a satisfactory level in the concerned outcome for 4 periods of assessment. The result shown in Table 8 is based on the scale described in Table 3. The items (ME + EE) include the combined percentages of respondents who strongly agree and agree.

Table 8 and Fig. 7 show that there is a consistency between continuous e-assessment results and indirect assessment related to students' perception.

6. Comparison with the Literature Survey

This section provides insights into the literature review of e-assessment practices, which have been

Table 7. Group satisfaction related to result shown in Table 3

		Period t1	Period t2	Period t3	Period t4
Student Outcomes' Statistics	EE	0	0	0	3
	ME	12	13	14	15
	PE	3	7	5	0
	DNME	5	0	1	2
Cumulative Achievement (ME + EE)		60.00%	65.00%	70.00%	90.00%
EE & ME satisfactory exceed 65%		PE	ME	ME	ME

Table 8. Correlation between student outcome achievement and indirect assessment

		Period t1	Period t2	Period t3	Period t4
Continuous e-assessment	Cumulative Achievement	**60%**	**65%**	**70%**	**90%**
Indirect assessment	Self-confidence	65%	75%	80%	90%
	Motivation	75%	85%	90%	95%

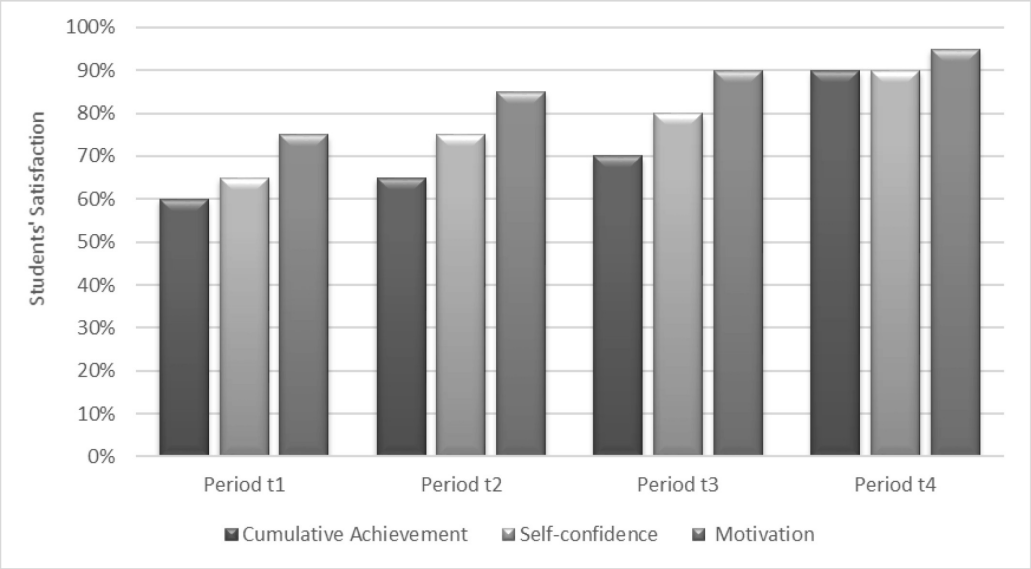

Fig. 7. Cumulative Achievement of SLOa vs Indirect Assessment.

presented above. Table 9 illustrates the main characteristics of the literature review papers. The included studies target students, teachers, and university graduates.

The main findings show that despite different methods and different objectives, the assessment practices display various similarities such as the context of assessment quality concerns as well as the increasing of the feedback and students' engagement. Furthermore, all papers implement diverse assessment methods such formative and summative assessment; e-assessment, outcome assessment, etc.... A variety of assessment formats such as collaboration, project assessment and the traditional quiz/multiple choice format. However, all these methods are inherently macroscopic and do not persuade continuous improvement in SLOs during the study period. Most of these methods provide only qualitative results. The outcomes depend on students' and teachers' feedback gathered at the end of semester. Therefore, they did not use methods which can aggregate students' outcome results and generate information about students' cumulative achievement of each outcome. These studies asses and measure impacts in terms of student performance based on students' perceptions. Yet, there is not any comprehensive monitoring of a students' progress specific assessment technique.

Moreover, all the assessment process presented in this literature survey illustrate their potential as well as the challenges to be encountered. These challenges indicate that many more steps have to be followed for the effective implementation of continuous e-assessment method at all education levels. In this context, we proposed an innovative formative and summative continuous e-assessment methodology which provides, in real time, after each e-

Table 9. Overview of literature surveys' assessment objectives, assessment methods and formats

Papers	Assessment objectives	Assessment methods	Assessment formats
[15]	Improve students' skills and outcomes Improve feedback to students	Formative E-assessment Model	Grade book, competencies, progress bar, knowledge assessment, and skill assessment module
[16]	Help teachers in order to track the students' learning process	E-assessment system which supports the formative assessment mode	Simple types of questions, e-assessments in computer engineering education
[17]	Implement a continuous assessment to evaluate and assess a learner's attributes	Teachers' formative & summative assessment	Questionnaires, focus group discussion, documents and interviews
[18]	Define a continuous evaluation tool for deeper learning to find a way that makes students work continuously during the course	Continuous assessment based on three case studies where the main material consists of teachers' experiences and student feedback	Traditional exams, individual theoretical assignments and group lab assignments
[19]	Propose an Adaptive Smart Student Assessment	Adaptive smart student assessment models where instructors can create contents that directly relate to students and determine students' preferred learning styles	Online test, appropriate content and questions to create a learning style
[20]	Propose adaptive assessment system	Assessment process which includes model, to gather the learning process from the perspective of learner and analyzes the gathered evidences and detects which evidences are relevant to update the learner/student profile	Activity, question exercises done by learner
[21]	Implement a continuous assessment to improve students' performance	Questionnaire that aimed to examine the relationship of different types of continuous assessment and student properties with academic achievement	Questionnaire Assignments and homework
[22]	Explore and highlight the effect of continuous assessment strategies for English language studies	Views of the faculty regarding the academic performance of students. Use questionnaires to collect data in qualitatively and quantitatively manners	Questionnaire
[23]	Propose a continuous feedback to improve the knowledge and skills acquired by students	''pre-test'' and ''post-test'' strategies, which can detect students' academic performance and provide feedback to students	Pre-test, post-test
[24]	Design a continuous assessment methodology	Examiner's summative assessment which can be automatically assessed and gave immediate feedback to students	Computer programming course, practical programming exercises
[25]	Prose an e-assessment system to help student, teacher, institution, and education aim. help teachers to improve the quality of feedback and reduced manual correction of test errors	Electronic assessment and analyze the response and track the progress of the students	Test or assignment
[3]	Develop an academic advisor agent which using continuous assessments to improve deaf student learning outcomes	Adviser agent focuses on continuously improve the Students Learning Outcomes by measuring their achievement periodically at the end of predefined terms.	Periodic e-assessment exams, adaptive activity

assessment of each SLO covered by many courses at a given period, first a comprehensive dataset on students' performance and perception concerning the outcomes' achievement, second a feedback to students about their progress, third suggest adaptive actions of improvement, and finally generates at the end of each semester a SLO-T reflecting the progress of students' achievement and it will be delivered to the student accompanying their traditional transcript. This SLO-T will facilitate a microscopic status to learners, educators as well as employers thus enabling focus identifications of the capabilities and limitations for lifelong skills development. Our solution is designed to be applied in a normal formal education environment without significant costs. Therefore, with small updates, it has a potential for replication in other colleges even with different type of educational program, but with the voluntary engagement of educators as well as the motivation of students. In addition, the

CAM is potentially suitable for blended learning and face-to-face courses and for the assessment of other competences based on the learning outcomes' concepts.

7. Limitations of the Research

At the end of this study, we elaborate a continuous e-assessment report in which the achievement of the student outcomes is assessed, the survey and other opinions gathering from faculty members and students. This report is then submitted to the Assessment Committee. After analyzing it, the Assessment Committee identified three major limitations in this research and proposed some action plans to improve the assessment objectives.

- First, some faculty members, even though they said they were satisfied with this type of assessment, but they stated that the most important impact of this e-assessment method is that it requires more time and effort to evaluate as per each student learning outcome for each student in addition to an action plan suggested to the students in order to improve their outcomes. Concerning this point, after consulting the Assessment Committee suggested following recommendations: First, to classify the SLOs in three categories: skills outcomes, knowledge outcomes, and values outcomes. Second, to select one SLO of each category which has a highest weight from the different courses per period. Third, to ask each courses' coordinator to work on the previous actions to facilitate its implementation. Finally, to involve tutors in this type of assessment.
- However, since the method is fully automated, less human involved activities are required. Thus, each educational program can apply this assessment with minimal effort, just set and present the student learning outcomes of their learning program and define their weights in each course. Also any educator or student unfamiliar with technology needs at the beginning a simple training to easily use the e-assessment method. However, with a view to encourage further replication of the CAM in different colleges, a toolkit will be developed -a step-by-step implementation guide- supporting students and educators.
- Second, according to students, at the beginning of COVID-19 pandemic, all their family members are working from home, which makes internet connections slow and can contribute for them falling to achieve their outcomes. In this context, the Assessment Committee asked the Computer Center in our College to serve and provide technical support for students by preparing an open laboratory for them.
- Finally, we used a small though representative sample in our validation phase. To generalize the outcomes of this study, larger sample size and degrees of freedom are needed to deal with this problem, we will use, during this academic year a larger sample size, including different levels of students, to ensure that the sample is considered representative of all students.

8. Conclusion

This research aimed to introduce a continuous e-assessment method in a multi-agent blended learning system in order to improve and to achieve the students' learning outcomes. In this context, we developed a continuous e-assessment method to (a) monitor and measure the progress of each students' learning outcomes during the entire period of an educational level and (b) eventually, identify the weaknesses and propose adaptive corrective actions to improve the student outcome achievement after each term. The evaluation of the proposed solution was performed on a selected student learning outcome covered in eight courses spread over four semesters, on a group of students in our computer science department. While continuously assessed, the students were able to improved their learning outcomes as reflected in the Results section.

Moreover, students' perception has revealed a high level of satisfaction based on an indirect assessment survey conducted on the study population as detailed in the discussion. When compared both continuous e-assessment and indirect results were found consistent. The use of our Multi-Agent Blended Learning System is not restricted to the use of the educational models described in this study. It can also be applied to other pedagogical approaches, from traditional ones based in courses and SLO to new proposals of blended learning involving the use of continuous e-assessment of SLO.

In future research, we plan in short-term research goal to implement the assessment committee action plans outlined in the Discussion concerning the limitations of our work to investigate possible improvements. Whereas my ultimate long-term research goal is to enhance our continuous e-assessment method by using deep learning algorithms to predict students' performance and improve their learning outcome achievement.

Acknowledgements – This work has been funded by the Research Center in the College of Computer and Information Sciences, King Saud University. We also thank the reviewers for their useful comments to improve the quality of our manuscript.

References

1. ABET Accreditation Board for Engineering and Technology, https://www.abet.org/accreditation, Accessed 07 October 2021.
2. Saudia National Education & Training Evaluation Commission. https://www.etec.gov.sa Accessed 07 October 2021.
3. H. Salah, S. Fahman, M. Hassan and A. Mohammed, Continuous improvement of deaf student learning outcomes based on an adaptive learning system and an Academic Advisor Agent, *Computers in Human Behavior*, **92**, pp. 536–546, 2017.
4. H. Salah and M. Hassan, Web Application for an Adaptive Multi-Agent E-Learning System: A Continuous improvement of e-content, *Journal of Web Engineering*, **13**, pp. 67–86, 2014.
5. L. McMillan, T. Johnson, M. Parker, W. Hunt and E. Diane, Improving Student Learning Outcomes through a Collaborative Higher Education Partnership, *International Journal of Teaching & Learning in Higher Education*, **32**(1), pp. 117–124, 2020.
6. O. Rashwan, I. Abu- Mahfouz and M. Ismail, Student-Centered Assessment of the Capstone Design Project Course in Mechanical Engineering Program, *International Journal of Engineering Education*, **36**(3), pp. 998–1008, 2020.
7. N. Abu Bakar and A. Norlidah, Learning Outcomes and Student Perceptions in Using of Blended Learning In History, *13th International Educational Technology Conference*, Malaysia, May 13–15, pp. 1–16, 2013.
8. C. Dziuban, C. R. Graham, P. D. Moskal, A. Norberg and N. Sicilia, Blended learning: the new normal and emerging technologies, *International Journal of Educational Technology in Higher Education*, **15**(3), 2018.
9. L. Ning, G. Zhidong and Q. Xiaomei, The Theory and Application of Blended Learning, *Proceedings of the 2017 International Conference on Economic Development and Education Management*, China, December 16–17, 2017.
10. K. Suzuki, From Nine Events of Instruction to the First Principles of Instruction: Transformation of Learning Architecture for Society 5.0, *Blended Learning: Re-thinking and Re-defining the Learning Process*, Lecture Notes in Computer Science, Springer, Cham, pp. 3–15, 2021.
11. J. Poon, Blended learning: an institutional approach for enhancing students' learning experiences, *Journal of online learning and teaching,* **9**(2), pp. 271–288), 2013.
12. R. M. Clarki and A. Kaw2, Enhancing Student Outcomes in a Blended Numerical Methods Course for Engineers: The Case for Practice and Cumulative Tests, *International Journal of Engineering Education*, **37**(3), pp. 585–593, 2021.
13. T. Iwan, S. Eko, Y. Durotul and A. Adi Apriadi, Improving IPS Learning Results through Learning Media Playing King Ludo, *American Journal of Educational Research*, **6**(8), pp. 1078–1084, 2018.
14. M. J. Kintu, C. Zhu and E. Kagambe, Blended learning effectiveness: the relationship between student characteristics, design features and outcomes, *Int J Educ Technol High Educ*, **14**(7), pp. 1–20, 2017.
15. E. Hettiarachchi, M. Enric, A. Maria and G. Ana-Elena, Introducing a Formative E-Assessment System to Improve Online Learning Experience and Performance, *Journal of Universal Computer Science,* **21**(8), pp. 1001–1021, 2015.
16. H. Enosha, I. Balasooriya and A. Maria, e-Assessment for Skill Acquisition in Online Engineering Education: Challenges and Opportunities, *Formative Assessment, Learning Data Analytics and Gamification*, Elsevier, pp. 49–64, 2016.
17. G. S. Walde, Assessment of the Implementation of Continuous Assessment: The Case of METTU University, *European Journal of Science and Mathematics Education,* **4**(4), pp. 534–544, 2016.
18. P. Pietikäinen and R. Karinen, Continuous assessment as a tool for deeper learning, *44th Annual Conference of the European Society for Engineering Education*, Belgium, September 12–15, 2016.
19. A. Dalal, M. Reda and S. Mostafa, ASSA: Adaptive E-Learning Smart Students Assessment Model, *International Journal of Advanced Computer Science and Applications*, **9**(7), pp. 128–136, 2018.
20. B. David, B. Xavier, G. Ana-Elena and R. Elena, Adaptive e-Assessment System: A General Approach, *International Journal of Emerging Technologies in Learning*, **11**(07). pp. 16–23, 2016.
21. D. Indira, V. P. Floris, W. Michiel and A. Wilfried, Explaining individual student success using continuous assessment types and student characteristics, *Higher Education Research and Development*, **37**(5), pp. 937–951, 2018.
22. S. Rana and R. Zubair, The Reality of Continuous Assessment Strategies on Saudi Students' Performance at University Level, *English Language Teaching*, **12**(12). pp 132–142, 2019.
23. L. G. Lemus, J. M. Montañana, F. Buendía and J. Poza-ujan, Computer-Assisted Method Based on Continuous Feedback to Improve the Academic Achievements of First-year Students on Computer Engineering, *Computer Applications in Engineering Education,* **23**(4). pp. 610–620, 2015.
24. L. Rosales-Castro, A. Laura, F. Andres, G. Fabio and C. Jorge, An Interactive Tool to Support Student Assessment in Programming Assignments, *IBERAMIA*, Costa Rica, November 23–25, pp. 404–414, 2016.
25. A. Nuha, W. Gary and W. Mike, Advantages and Challenges of Using E-assessment, International Journal of Information and Education Technology, **8**(1), pp. 34–37, 2018.
26. H. Salah and M. Hassan, Adaptive e-learning system based on agents and object Petri nets (AELS-A/OPN), *Computer Applications in Engineering Education*, **23**(2), pp. 170–190, 2015.
27. P. Spooren, D. Mortelmans and J. Denekens, Student evaluation of teaching quality in higher education: development of an instrument based on 10 Likert-scales, *Assessment & Evaluation in Higher Education*, **32**(6), pp. 667–679, 2007.

Appendix

This section details the calculations of the achievement value of the outcome SLO_a, concerning student named $S1_1$ Table 3, using CAM during four periods. This outcome is covered by eight courses which are distributed on four periods. All the outcome weights are defined in Fig. 6.

– **Period t_1** (C_1 and C_2) with weight value: $\alpha_1 = 10\%$ and $\alpha_2 = 10\%$. We calculate the student achievement on this SLO with the function:

$$SLO_{y,t_p} = \left(\frac{CO_{y,t_p}}{\beta_{y,t_p}}\right), \text{ where } CO_y, t_p = \sum_{C=1}^{s} (CA_{c,y,t_p} \times \alpha_c)$$

and the weight $\beta_{y,t_p} = \sum_{C=1}^{s}(\alpha_c)$ is the summation of weight α_x for every related Course C_x of specific SLO_y.

These operations will be done by the following function based on the results in Fig. a and Fig. b:

$$CA_{1,a,1} = 78.7 \; with \; \alpha_1 = 10\%, \quad CA_{2,\alpha,1} = 78.48 \; with \; \alpha_2 = 10\%$$

$$CO_{\alpha,1} = 78.7 \times 0.1 + 78.48 \times 0.1 = 15.718 \quad SLO_{\alpha,1} = \frac{15.718}{20} = 0.7859 = 78.59\% \approx \mathbf{79\%}$$

– **Period t_2** (C3, C4 and C5) with weight value: $\alpha_3 = 10\%,\ \alpha_4 = 15\%$ *and* $\alpha_5 = 15\%$.

$CA_{3,a,2} = 93 \; with \; \alpha_3 = 10\%$

$CA_{4,a,2} = 79.67 \; with \; \alpha_4 = 15\%$

$CA_{5,a,2} = 77.34 \; with \; \alpha_5 = 15\%$

$$CO_{a,2} = 93 \times 0.1 + 79.67 \times 0.15 + 77.34 \times 0.15 = 32.85.$$

$$SLO_{a,2} = \frac{31.8515}{40} = 0.79628 = 79.62\%$$

Cumulative achievement of SLO_a ($cmO_{a,2}$) at period t_2 will be

$$cmO_{a,t2} = \frac{15.718+32.8515}{20+40} = 0.8194 \approx \mathbf{82\%}$$

– **Period t_3** one course C_6 with weight value: $\alpha_6 = 25\%$
$CA_{6,a,3} = 90.9$

We have one course in period t_3, then $CO_{a,3} = 90.9 \times 0.25 = 22.73 \quad SLO_{a,3} = CA_{6,a,3} = 90.9\%$

Cumulative achievement of SLO_a ($cmO_{a,3}$) at period t_3 will be $cmO_{a,3} = \frac{15.718+32.8515+22.73}{20+40+25} = 0.8388 \approx \mathbf{84\%}$

– **Period t_4** there are two courses (C_7 and C_8) with weight value: $\alpha_7 = 5\%$ *and* $\alpha_8 = 10\%$.

$CA_{7,a,4} = 91 \; with \; \alpha_1 = 5\%$

$CA_{8,a,4} = 91.3 \; with \; \alpha_2 = 10\%$

$CO_{a,4} = 91 \times 0.05 + 91.3 \times 0.1 + 13.68$

$$SLO_{a,4} = \frac{13.68}{15} = 0.912 = 91.2\%$$

Cumulative achievement of SLO_a ($cmO_{a,4}$) at period t_4 will be

$$cmO_{a,3} = \frac{17.568+31.8515+22.73+13.68}{20+40+25+15} \approx \mathbf{86\%}$$

Table i. summarizes the student achievement during each period related to the outcome SLO_a and the outcomes variation of student learning outcomes achievement through four periods. As we have seen, the achievement of evaluations using CAM algorithm has an evidence proves that the SLO will be improved using CAM algorithm.

Table i. Student achievement result of Student S11 during each period related to the outcome SLOa

Period	Course	Weight Value of SLO_a in each course	Student Achievement of SLO_a ($CA_{Ci,a,ti}$)	Cumulative Achievement of SLO_a ($cmO_{a,ti}$)
t_1	C1	10%	78.70	**79**
	C2	10%	78.48	
t_2	C3	10%	93.00	**82**
	C4	15%	79.67	
	C5	15%	77.34	
t_3	C6	25%	90.90	**84**
t_4	C7	05%	91.00	**86**
	C8	10%	91.30	

Fig. a and Fig. b show some of the detailed calculations of student achievement in SLO_a on C1 and C2 during period t1.

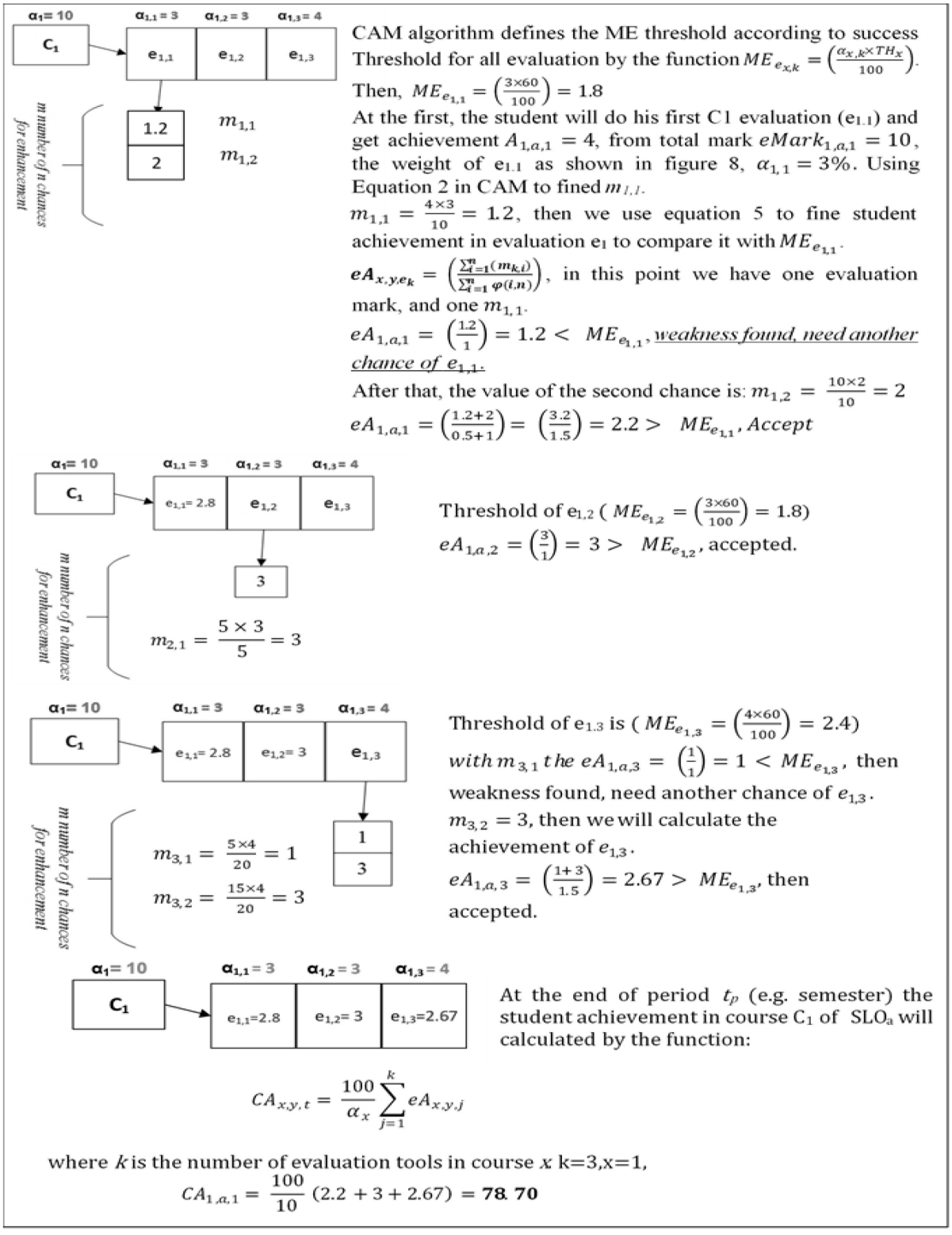

Fig. a. Student achievement of SLOa in C1 during t1.

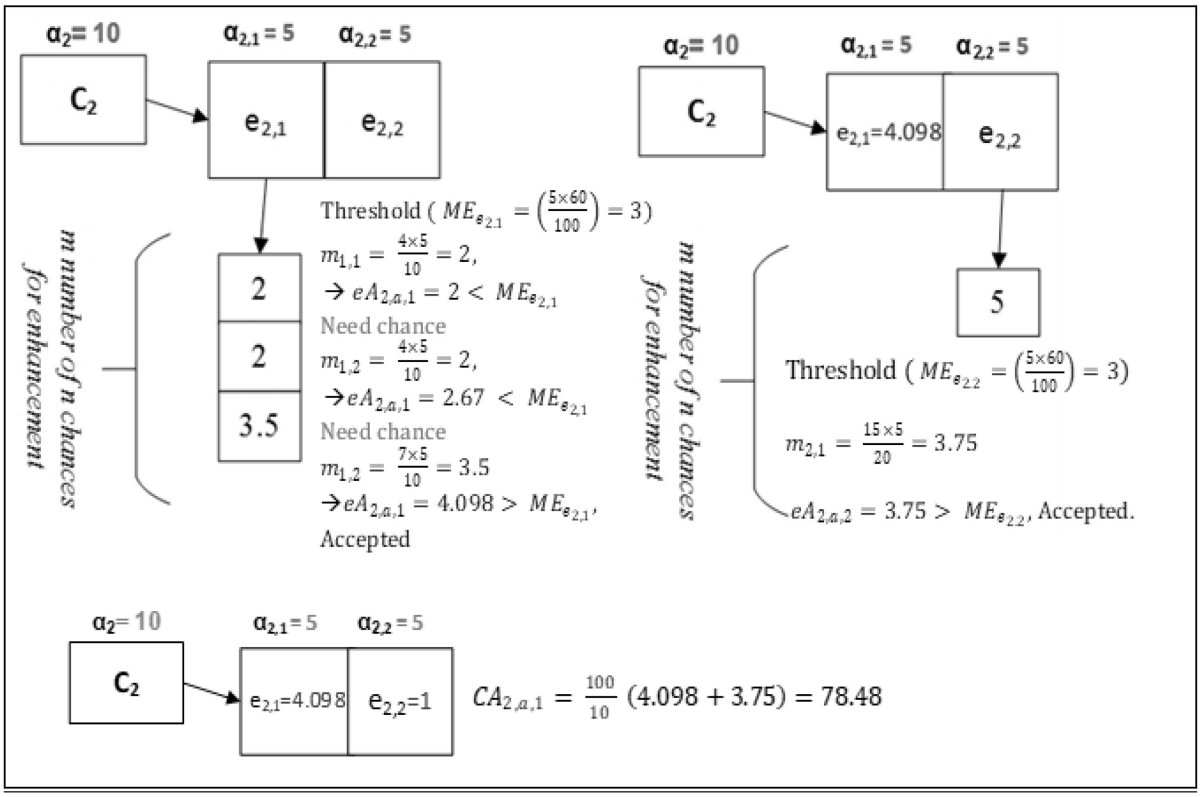

Fig. b. Student achievement of SLOa in C2 during t1.

Salah Hammami, PhD Associate Professor in the Department of Computer Science in King Saud University. He received his PhD in Computer Science from the University of Manar, Tunis, Tunisia. He has published many papers in international journals and conferences. His current research interests include technology enhanced learning, intelligent educational agent, continuous improvement of students learning outcomes, and e-learning for special needs students.