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Article

A Quantitative Assessment of Rubrics Using a Soft Computing Approach

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Abstract: This study aims to elucidate a soft computing approach for quantitative assessment of the scoring grade or rubrics for students in an outcome based education system. The intended approach resorts to a fuzzy membership based assessment of the different parameters of the scoring system, thereby yielding a novel and humanly assessment technique. The selection of the membership functions is based on the human behavior so as to make a realistic representation of the scoring strategy. The novelty of the proposed strategy lies in assigning fuzzy membership based weighted scores instead of simply assigning score bands to rubric categories, as is performed in normal rubrics based assessment. Comparative results demonstrated on a case study of Indian education scenario reveal the effectiveness of the proposed strategy over other fuzzy membership and normal rubrics based assessment procedures.

Keywords: OBE; OBTE; graduate attributes; rubrics; fuzzy sets.

1. Introduction

In the early days of higher education, the conventional paradigm of testing knowledge and teacher focused learning played a vital role but nowadays active, students-centered learning and thoughtful deliberative assessment are given the main emphasis [1]. In many modern-world countries, the move from summative appraisal to developmental appraisal has occurred. The word performance evaluation of a student in learning alludes to different devices the teachers use to quantify and record the abilities procured, learning progress, scholarly evaluations and so on by the students. Rubrics is one of the classical aggregation method to help understudy as they take part in oneself managed learning process. This method is also applied for the grading of the general presentation of the students throughout a period of a semester or one year however doesn't ponder consistent execution of understudies. On the contrary, self-controlled learning is an student driven procedure in which a student ponders the traits of their own work, investigate how well their work meets the stipulated criteria, and modifies to meet the criteria. This process also helps the faculty members. As discussed in [2], rubrics is characterized as a scoring apparatus employed to assess students execution in a predefined outcome region dependent on a list of criteria portraying the attributes of items or exhibitions at different degrees of achievement. In these days, the grading rubric tool aimed for different courses are generally utilized for both developmental and summative evaluations. A rubric is organized in order to evaluate the accomplishment of learning destinations set by course specialists against a great deal of models at each period of learning. For different courses, distinctive scoring rubrics are planned, for instance, a rubric for engineering students is different from that of

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arts student.

"Rubric" originated from the Latin word "Rubber", which signifies "Red". In the early stages, rubric was a lot of directions connected to the law and was scripted in red [3]. Basically, rubrics are applied magisterially to guide people by expressing the instructive reason for a course/program/task and how the course learning destinations/criteria are met with, to achieve the normal principles. The rubrics are organized and applied to choose assessments or degrees which learning checks are refined by the students. In this manner the criteria and execution level depictions in the rubrics help students comprehend what the ideal performance is and what it resembles [4]. The students' performance is evaluated by the Bloom's taxonomy levels. Typically rubrics are talked about with the students prior to beginning the course to ensure that learning results and rules for which scoring rubrics are organized are clearly understood by the students. The rubric can be even altered throughout figuring out how to improve the standard of learning.

The fundamental features of the rubrics are evaluation criteria, quality definitions and scoring strategy [5]. Evaluation criteria are the elements that an assessor thinks about while deciding the nature of a student's work. Likewise depicted as a lot of indicators or a rundown of rules, the criteria mirror the procedures and substance made a decision to be significant [6]. Quality definitions give a point by point clarification of what a student must do to exhibit an aptitude, capability or basis so as to accomplish a specific degree of accomplishment, for instance poor, fair, good or excellent. To give feedback to students and for scoring purposes, the quality definitions address the need to recognize great and poor reactions. Scoring methodologies for rubrics include the utilization of a scale for deciphering decisions of an item or procedure. Utilized as a component of a student-focused way to deal with evaluation, rubrics can possibly assist students with comprehension the focuses for their learning and the gauges of value for a specific task, as well as make reliable decisions about their own work that can advise amendment what's a more, improvement.

The paper is organized as follows. Section 2 highlights the motivation behind the present work and the salient contributions. A brief review of existing literature in this field is elucidated in Section 3. Section 4 provides the objectives of ABEt accreditation system with emphasis on the importance of Outcome Based Education (OBE). A brief overview of the accreditation system in place in India is presented in Section 5. Section 6 provides the basis concepts of the soft computing paradigm entailing fuzzy sets and fuzzy logic. A bird's eye view of the assessment rubrics is provided in Section 7. A detailed discussion on rubrics based assessment methodology with reference to the different assessment tools and techniques is provided in Section 8. Section 9 throws light on the methodology for quantitative assessment of rubrics in order to evaluate students' performances based on fuzzy set theory based scoring mechanism. Section 10 draws a conclusion on the findings of the proposed method.

2. Motivation and Contributions

The assessment of the students' performances per the different courses offered by an educational institution under the outcome based education system is generally qualitative in nature given the subjective nature of the underlying assessment rubrics. As such, the gradation or ranking of the students based on their performance adjudged on the scale of the essential graduate attributes remains far from being realistic and is prone to the subjectivity of the grading system. The very few quantitative methods existent in this regard are based on pure heuristics and are not fully qualified to derive an objective assessment of the students. Hence, the primary motivation behind this work is to develop a quantitative assessment mechanism for the students' performances by means of a model which is able to quantify the qualitative assessment rubrics by taking recourse to the vagueness handling capability of fuzzy sets. It may be noted that in normal rubrics based assessment, the scores are simply asigned to the rubric categories without any loss of generality. Such an assignment procedure does not take into account the relative weightages of the scores

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(often reflected by an objective grade) that are assigned to a particular rubric category, thereby making the assessment a trivial process having no critical analysis of the underlying performance.

The salient contributions of this work are enlisted as follows.

1. Modeling of the subjective nature of the assessment rubrics by means of a fuzzy set theoretic model which is capable of handling the uncertainty and vagueness in the assessment rubrics.
2. Using an appropriate fuzzification method which resembles the underlying human reasoning behind the design of rubrics.
3. Developing a fuzzy scoring mechanism to evaluate the students' performance on a scale of 1% to 100% thereby yielding a clear grading/ranking system based on the evaluated fuzzy scores.
4. Applying the model on example scores using Open Right Sigmoidal, Gaussian and Triangular membership functions.

3. Review of Literature

Andrade [7] presented a short review the structure and purposes of rubrics. The benefits and the shortcomings of the rubrics also discussed as both teaching and grading tools. To help student learning, the rubric could be imparted to the students in a student-centered methodology [8,9]. Reddy and Andrade [10] presented a detailed review on the experimental research on the utilization of rubrics at the post-optional level, distinguishes holes in the writing and proposes zones needing investigate. Rubrics applied for evaluating as well as can be locked in as educating instruments [10]. At the point when utilized by a teacher as a piece of developmental evaluation, they can assist students with understanding both the all-encompassing nature and/or explicit examination of learning anticipated, level of learning expected, and afterward settle on a choice about the present degree of figuring out how to illuminate modification and improvement. Bhuruthram [11] showed with the experimental data that rubrics recognized as a important tool for the teacher's practice and in curriculum review and development. It is also showed that the rubrics helps the teacher to upgrade his teaching practice and course design. The utilization of rubrics as an appraisal and developmental assessment tool, situated toward learning and the procurement of abilities is spreading in colleges/ universities alongside learning-focused showing model, to a great extent advanced by different countries [12]. Hafner and Hafner [13] investigated the centers around the legitimacy and unwavering quality of the rubric as an appraisal apparatus for student peer-group assessment with an end goal to additionally investigating the utilization and adequacy of the rubric. A detailed quantitative study of the rubric had been done on both the students and the instructors through out a year.

Fuzzy set theory has often been employed to several real-life engineering problems involving multiple attributes. Analysis of multiple attributes in decision making has been dealt with a hesitant fuzzy balancing and ranking (HF-BR) mechanism [14]. In this approach, the hesitant fuzzy sets are obtained from the defined hesitant fuzzy terms. In respect to the other alternatives, the outranking matrix of this method showed an impressive result in respect to the selected attribute. An implicit preordering under hesitant conditions was developed by triangularizing the outranking matrix in [14]. A ranking approach referred to as the interval-valued hesitant fuzzy set (IVHFS) was employed to evaluate the candidate green suppliers under selected criteria in a multi-period approach [15]. The main objectives of this method is to minimize errors and data losses. IVHFS method was applied to evaluate the risks in IT outsourcing [16]. The judgment errors are minimized by introducing an additive weighting method. Gitinavard [17] presented a hybrid group decision-making approach for the sustainable evaluation of construction projects in strategy-focused conditions. A hybrid hesitant fuzzy group decision-making approach is introduced which is dependent on three parts, (i) determination of the experts' weights by a hesitant fuzzy collective wisdom weighting (HFCWW) [17] method, (ii) evaluating the the criteria weights by employing a hesitant fuzzy preference weighting (HFPW) [17] process and (iii) a hesitant

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fuzzy utility index [17] is used to sort the candidate strategic projects.
On similar lines, a computer based fuzzy method, named **fem** was proposed to replace two existing students' answerscript evaluation method, i. e. grading method and traditional marking method [18]. A matrix-valued making method was also presented in this article [18] but this method is unable to evaluate student performance for the muddled coordinating activity of answer scripts [19]. To overcome this problem, a generalized method was proposed by Chen and Lee [19]. Fuzzy based cricketer execution assessment model introduces a universal position forecast of a cricketer and furthermore the impact of each info parameter on execution [20]. A novel method [21] was exhibited utilizing fuzzy logic to overcome the drawbacks of the traditional technique for evaluation performed in Universities. To execute this methodology, student attendance, internal and external marks are considered as the input parameters. A Fuzzy Probabilistic Neural Network model was presented by Arora and Saini [22] to classify and anticipate students' performance using arithmetical and statistical techniques. The proposed model can be applied as a customized student execution forecast part and can handle the prevailing loose data, while empowering the portrayal of the student displayed in a etymological structure. An intelligent tutoring system, named Design Pattern Teaching Help System (DEPTHS) was proposed for learning software design patterns [23]. In this method, the proposed strategy used to display the information of a student just as the standard based method applied for evaluating the student's information. Genetic algorithm in mix with artificial neural network was applied to defeat the issues in predicting academic success in higher education environments and furthermore to discover the components which impact the performance of students [24]. A fuzzy model was presented to evaluate the students' performance through the establishment of performance [25]. Lin *et al.* [26] proposed an online genetic algorithm-based remedial learning system to improvise students' comprehension of object-oriented programming (OOP) ideas by fitting customized learning materials agreeing to every student's qualities and shortcomings.
To make free classroom time for student focused activities, similar to dynamic and issue based learning, an idea of modern classroom has been introduced where content delivery includes video lectures watched outside of the classroom [27]. Effectiveness of the inverted classroom in comparison to the traditional classroom presented in three regions: 1) content inclusion; 2) understudy execution on conventional tests and test issues; and 3) student perceptions and impression of the transformed study hall design [27]. Medeiros *et al.* [28] presented past efficient literature reviews by tending to a progressively contemporary setting of introductory programming. In this article, the authors categorized the introductory programming difficulties, and features key issues for an examination guide on basic programming learning and instructing in higher education. The utilization of modern and blended learning in an electrical machines course is narrated with expanded student commitment, pass rate scores over the GPA range [29]. Song *et al.* [30] presented an efficient way to deal with MATLAB problem design and automated appraisal. This method portrayed in view of the experience working with the MATLAB server furnished by MathWorks and incorporated with the edX gigantic online open class (MOOC) platform.

4. ABET Accreditation System

Accreditation is a kind of value confirmation process under which administrations and tasks of instructive establishments or projects are assessed by an outside body to decide whether relevant standards are met. If those guidelines are met, the accredited status is surrendered by the office. For this process, the Council for Higher Education Accreditation of United States (U.S.) formed a recognized accreditation agency, named Accreditation Board for Engineering and Technology, in short, ABET. ABET is non-administrative and non-profit accrediting association that authorizes post-secondary education programs in applied science,engineering and engineering technology and computing and also helps the academic institutions in arranging their course curriculum [31]. The main goal is to promote scholarly improvement of a college or university those are keen in engineering

and related professions and give specialized help to maintain the quality standards established by the engineering–related regulatory authority for which the program prepares its students. Globally, ABET is viewed as one of the most regarded bodies driving this procedure in the engineering and technology disciplines. ABET planned a new Engineering criteria in 2017 to address the issues of the engineering and the industry field. It assists with assessing the ampleness of planning engineering education programs by focusing on an examination and evaluation measure that ensures the achievement of a bunch of educational targets and results [32]. A significant component of these criteria is the foundation of a consistent improvement process through goals and outcomes assessment and appraisal methodology [33]. ABET divided its accreditation criteria in two sections, i. e. a set of important “hard" engineering skills as well as another significant set of six soft skills. Teamwork, communication, professionalism within a global and societal context, understanding ethics, knowledge of contemporary issues and lifelong learning are the soft skills criteria of ABET [33,34].

The readiness of the ABET Self Study can be an overwhelming periodic process. It has been observed in most of the cases that a single faculty member has been designated as the program coordinator and all activities identified with accreditation tumbles on him. He not exclusively should turn into a specialist at all parts of accreditation, yet in addition must teach individual employees of their jobs and duties in the accreditation planning process [35]. The evaluation of student outcome can benefit the effective performance measurement, involvement of large number of faculty members and utilization of outcomes from an enormous number of the necessary courses in the curriculum.

For evaluation of the educational progress, each and every educational institute must maintain a quality assurance system to reach ABET criteria. In this direction, each department have to build up an appropriate mission. Secondly, a program committee will be formed to get ready for accreditation, to set up educational objectives and results for every degree program. To guarantee clarity, the program committee must revise and rephrase the objectives and the outcomes of the program frequently and iteratively.

4.1. Importance of Outcome Based Education (OBE)

In this ever changing world, education system throughout the world is changing quickly and persistently to cope up with the fast developing technology. To adapt these types of technological improvements, the educational institutions should create more technically knowledgeable students who can grasp any new technology very fast and efficiently. Subsequently to beat the prerequisite, it is required to move from conventional instruction framework to Outcome Based Education (OBE), which incorporates Program Outcomes (PO), Program Specific Outcomes (PSO), and Course Outcomes (CO) [36]. Teachers should give emphasis on the learning improvement of the students instead of their conventional teaching. Through OBE, emphasis should be given from the students to finally accomplish when they complete their course as opposed to how they accomplished it. Outcome based education is characterized as a way to deal with education wherein choices about the curriculum are driven by the results the students should show before the finish of the course-professional knowledge, aptitudes, capacities, qualities and perspectives as opposed to on the educational procedure. Nowadays, the main objective of various higher education institutions in different countries is the student learning outcomes and evaluations. mainly, the OBE consists of competency-based learning measures and outcome-based quality affirmation checking [36]. As the predefined learning outcomes can be accomplished by the planned OBE, engineering programmes concentrated on the objectives and outcomes to achieve an OBE model of accreditation. One may get a clear picture from OBE program that what a student ought to have the option to do, structure the educational program, instructing learning procedure and appraisal to guarantee that the results are accomplished. As there is no specific teaching-learning methodology or strategy in OBE, different types of curriculum can be integrated in a syllabus. Significant is that the students accomplishes the results however his own specific manner. Building up an Outcome Based Education

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framework in higher education is the most ideal path for the student to accomplish their objectives after graduation.

Outcome Based Education is quickly picking up consideration around the world. OBE is applied to form a systematic approach to reform the curriculum in the educational sector in different parts of the world, like, Australia, Hong Kong, South Africa, United States, etc., to name a few. Since 1994, OBE program has been started in USA and they has been adjusted throughout the years [37,38]. Australia and South Africa received OBE strategies in the mid 1990s however have since been eliminated [39,40]. Hong Kong and Malaysia implemented OBE in the public schools and universities in the year of 2005 and 2008, respectively [41,42]. The European Union has proposed an education movement to concentrate on outcomes, over the EU [43].

5. Indian Perspective of Outcome Based Education

Engineering education across the world is currently passing through significant evolutionary stages and in India too, the changes are imminent. To align the outcome of engineering programs across the country with the Washington Accord (on International Engineering Alliance), the standards set by the regulatory bodies like National Board of Accreditation (NBA) are becoming binding on the colleges or Universities offering engineering programs. The administrators, educators and the entire fraternity of engineering faculty are feeling the heat as days are not far away when mere AICTE approval will not do and NBA accreditation will be mandatory for all in the business. It is therefore important for us to get ourselves oriented towards this new paradigm of engineering education which is Outcome Based.

Unlike traditional engineering education, apart from measuring technical knowledge and skills, the qualitative personality attributes that the students are supposed to acquire through the engineering courses are also measured in Outcome Based education. To do this, the first step is to frame a set of Program Outcomes (POs) in line with NBA's twelve Graduate Attributes (GAs) which describe what students are expected to know and be able to do by the time of graduation. The GAs are: Engineering Knowledge, Problem Analysis, Design/Development of Solutions, Conduct Investigation, Modern Tool Usage, The Engineer & Society, Environment & Sustainability, Ethics, Individual & Team Work, Communication, Project Management & Finance and Life Long Learning. All these are attributes that help a graduate become not only a competent engineer but a good manager and above all a sensible and social professional. The next step is to design the Assessment Rubrics i.e. the set of assessment components, measurable elements of performance under each component and grading criterion for each element towards continuous assessment of each of PO1 to PO12 the courses offered in an engineering curriculum. A given assessment component (e.g. class performance) of a PO (say PO1) may be assessed in n no. of courses (which are strongly related to that particular PO) in a semester. The average of n scores of a component will be counted while finding the total score of all components against a PO. Finally, scores of all the twelve POs will be collated to find the average score i.e. the degree of attainment of POs in a particular semester. The assessment components can be direct and continuous (e.g. class test, classroom demonstration/seminar, quiz, laboratory experiments), direct and one-time (e.g. semester exam, project presentation, grand viva) and indirect (e.g. co-curricular and extra-curricular activities, self assessment, departmental evaluation). All possible activities (beyond curriculum) having potential towards building up professional personalities of the students should be identified and listed as assessment components of related POs to carry the essence of Outcome based education. An engineering department should maintain student portfolio (for each student) containing semester-wise records of % score against each PO. The department should collate the records and certify a student's accomplishment of POs semester-wise, year-wise and at the time of graduation just as SGPA, YGPA and DGPA are to be calculated in parallel. Thus, the traditional assessment of engineering knowledge and skill (certified by University) is supplemented by assessment of all-round professional qualities of an engineering graduate.

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Gradually this PO-based certification will be standardized to be honored by the recruiting agency or academia where a young graduate might opt to pursue his post-graduation career.

Now the task of a teacher will be more challenging in this new system compared to that in conventional classroom-bound system. Instead of taking routine classes to cover the syllabus, conducting two/three class tests and checking assignments and papers in a semester, one has to observe and evaluate different elements of students' performance like communication skill, leadership skill, teamwork, discipline, body language & confidence, punctuality and many others, though not all of those for a given course, only the relevant ones. The focus should be on learning by students rather than spoon feeding as more learning is desirable than teaching. Students are most interested to learn mental and manual skills that have immediate relevance to possible job situations and professional life. Hence, students should be exposed to more open-ended problem based self-learning (emphasis on micro, minor and major projects) with restricted guidance. Teachers should be encouraged to use students' learning centric methods like the following ones:

- More case studies (incl. videos) than curriculum based flat lectures. Involve students in groups to study and solve typical cases in classrooms
- During lectures ask questions to the students, invite them in asking questions, raising relevant issues that helps better clarifications of topics taught
- Give oral or written quizzes to generate interest among the students
- Ask students to come to the board and explain something (on spot)
- Ask students to take the role of teacher and give classroom demonstrations and seminars (with preparation) and compete for best presentation awards

To survive and excel in the fast evolving education system we should continuously keep on improving the assessment formats and approaches to make it more and more precise and objective. Here a teacher can enjoy the freedom to modify the existing assessment components and introduce some innovative ones. Teaching can be more interesting with this outcome based approach if we can motivate ourselves to do some action research on effect of changes in methods and media of course delivery and assessment on learning and attainment of POs by the students.

6. Soft Computing Paradigm

Human intelligence has always been guided by abstract reasoning which cannot be quantified in the true sense of the term. The inherent reasoning imbibed in human beings due to a process of continuous learning is able to qualify real life objectives rather than being able to quantify them.

This type of human reasoning often leads to inaccurate, imprecise or vague understanding of the objectives. The degree of inaccuracy or imprecision or vagueness calls for repetitive and revised reasoning. Conventional computing paradigm often falls short in grasping the essence of this type of human reasoning due to the fact that the nature of such reasoning is not crisp or quantifiable. As a fallout, scientists and researchers have coined the term "soft computing" [44–47] to assess and adjudge the softness in the human reasoning capabilities. The resultant soft computing paradigm deals with the uncertainty, imprecision, vagueness in human understanding from a non-rigid (soft) perspective where measurements do not follow rigid boundaries.

The soft computing paradigm essentially comprises several tools in the form of neural networks (mimicking human brain), fuzzy sets and fuzzy logic (for imprecise understanding), evolutionary algorithms (having exploration and exploitation capabilities), rough sets (formal approximation of a crisp set) to name a few.

The following subsections illustrate brief overview of fuzzy set theory and its applications in addressing real life problems.

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6.1. Fuzzy Sets and Fuzzy Logic

A fuzzy set is a set having degrees of membership between 1 and 0 [44]. Partial membership exists when member of one fuzzy set is also a part of other fuzzy sets in the same universe. The degree of membership or truth is not same as probability, fuzzy truth represents membership in vaguely defined sets. A fuzzy set $\tilde{A}$ in the universe of discourse, $\tilde{U}$, can be defined as a set of ordered pairs as [44,46]

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)); x \in X\} \tag{1}$$

where, $\mu_{\tilde{A}}(x)$ is referred to as the degree of membership/degree of belongingness (or membership value) of the element x in the fuzzy set $\tilde{A}$. The height of a fuzzy set is given by the maximum membership of all the elements in the fuzzy set. For a normal fuzzy set, height of the fuzzy set is unity (1), else it is less than 1. The membership values of a fuzzy set are generally determined by means of fuzzifiers which operate on crisp values and convert them to fuzzy values. There are largely three types of fuzzifiers, (1) Singleton fuzzifier, (2) Gaussian fuzzifier and (3) Trapezoidal or triangular fuzzifier. When the height of a fuzzifier is less than 1, it is referred to as a submormal fuzzifier.
For a discrete and finite universe of discourse, $\tilde{U}$, the fuzzy set $\tilde{A}$ is given by [44,46]

$$\tilde{A} = \sum_{1}^{n} \frac{\mu_{\tilde{A}(x_i)}}{x_i} = \frac{\mu_{\tilde{A}(x_1)}}{x_1} + \frac{\mu_{\tilde{A}(x_2)}}{x_2} + \ldots + \frac{\mu_{\tilde{A}(x_n)}}{x_n} \tag{2}$$

where, n is a finite value.
In the real world, it is often difficult to determine whether a particular state is true or false. Given its multi-valued reasoning capabilities, fuzzy logic provides a flexible approach for the determination of such uncertainties. Whereas, in boolean system, truth value, 1.0 represents absolute truth value and 0.0 represents absolute false value, in a fuzzy system, there is no logic for absolute truth and absolute false values. However, there exists intermediate values which are partially true and partially false.
Fuzzy logic [44,46] forms the heart of a fuzzy rule base architecture [44,46], which comprises essentially four components.

- A Rule Base, which contains a set of rules of the form of *IF-THEN* conditions on the basis of linguistic information.
- A Fuzzification system for converting crisp inputs to fuzzy variables.
- An Inference Engine to infer on the degree of firing of each rule based on the fuzzy inputs. The fired rules are further combined to yield decisions.
- A Defuzzification system for converting the fuzzy outcomes yielded from the inference engine to crisp values. The type of defuzzification method employed depends on the system under consideration.

6.1.1. Gaussian Fuzzifier

The Gaussian fuzzifier is characterized by the Gaussian membership function which is often employed to represent vague, linguistic terms. Unlike other fuzzifiers, the Gaussian fuzzifier is more aptly similar in nature to human reasoning which is generally influenced by learning experience. The Gaussian membership function is represented by the Gaussian (shown in Figure 1) given by [44,46]

$$\mu_{\tilde{A}_i(x)} = e^{(-\frac{(c_i - x)^2}{2\sigma_i^2})} \tag{3}$$

where, σ_i and c_i are the width and centre of the i^{th} fuzzy set $\tilde{A}_i$, respectively.
The salient features of the Gaussain membership functions are:

- It is a local function although not strictly compact.
- It produces very smooth outputs.

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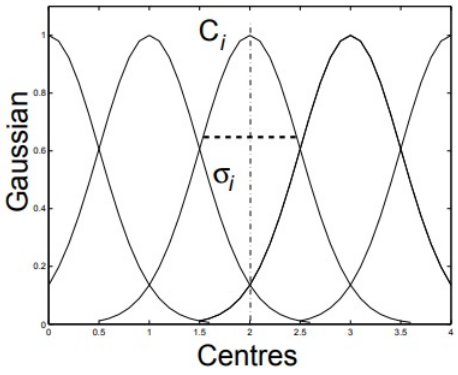

Figure 1. Gaussian Membership Function

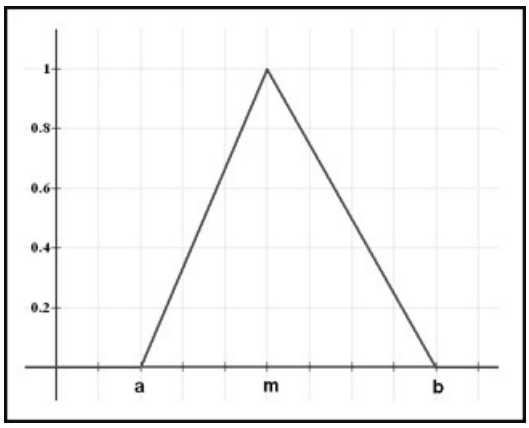

Figure 2. Triangular Membership Function

- The multivariate versions of the Gaussian functions can be formed from the product of univariate sets.
- The Gaussian fuzzy membership functions form the basis for connection between fuzzy systems and radial basis function (RBF) neural networks.

6.1.2. Triangular Fuzzifier

The Triangular fuzzifier is defined by a lower limit a, an upper limit b, and a value m where $a < m < b$ as given by [44,46]

$$\mu_{\tilde{A}_i(x)} = \begin{cases} 0 & x \leq a \\ \frac{x-a}{m-a} & a < x \leq m \\ \frac{b-x}{b-m} & m < x < b \\ 0 & x \geq b \end{cases} \tag{4}$$

A normal (height=1) Triangular fuzzifier is shown in 2. From Figure 2, it is clear that a Triangular fuzzifier exhibits two levels of membership of 0 (indicating the lowest membership) and 1 (indicating the highest membership). Hence, the Triangular fuzzifier does not encompass other degrees of membership grades between 0 and 1. As such, the decision making out of the fuzzifier is linear. However, human reasoning is seldom linear in nature and exhibits a varied amount of non=linearity. Thus, the Triangular fuzzifier often falls short in approximating the human decision making process.

6.1.3. Sigmoidal Fuzzifier

The Sigmoidal fuzzifier is based on the sigmoidal membership function given by [44, 46]

$$\mu_{\tilde{A}_i(x)} = \frac{1}{1 + e^{-a(x-c)}} \tag{5}$$

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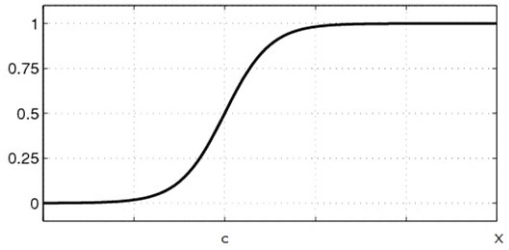

Figure 3. Sigmoidal Membership Function

where, a controls the slope of the membership function at the crossover point $x = c$.
A Sigmoid membership is inherently open right or left depending on the sign of the parameter a. Hence, it is suitable in those situations represented by the composite linguistic terms like “very large" or “very negative". A Sigmoidal membership function is shown in Figure 3.

7. Assessment Rubrics

As per education technology, the term “rubric" refers to “a scoring mechanism for evaluating and measuring the objective quality of the students based on their constructed responses". Rubrics comprise three elements, viz., (i) some evaluation criteria, (ii) some qualitative definitions of those criteria at different levels of achievement, and (iii) a scoring mechanism. The rubrics are often represented in a tabular format which can be used by teachers for marking assessment and by the students while planning for their work responses. It has been observed that when the rubrics are used in conjunction with formative assessment tools, bear a positive impact on the learning attitude of the students.
A scoring rubric is often used to express the quality expectations from a constructed task. As such, the scoring rubrics are used to define consistency in the grading criteria. Due to the fact that these criteria are public, the scoring rubrics allow both the teachers and the students to evaluate the quality of constructed responses, which often leads to some form of complex subjective assessment. Since the students are equally enable to evaluate the criteria, the scoring rubrics also help in proper self-evaluation, reflection, and peer review of the constructed responses submitted by them. The basic objective of the scoring rubrics is to facilitate accuracy and fairness in the assessment methods thereby paving the way for an efficient teaching/learning process. This integrated method comprising of performance and feedback is referred to as ongoing assessment or formative assessment.
Like any other evaluation tool, the main purpose of rubrics is to help assess performance of students. However, it also helps to decide on the types of performances which can be properly assessed.

7.1. Categories of Rubrics

Depending on the assessment methodology adopted, rubrics can be classified into two main categories - (i) Analytic Rubrics and (ii) Holistic Ribrics.

7.1.1. Analytic Rubrics

An analytic rubric is often represented by a grid with the students’ performance criteria listed in the leftmost column and the performance levels listed across the top row often using numbers and/or descriptive tags. The central cells of the rubric may be either left blank or may contain descriptions aboute the performance criteria for each level of performance. The scoring system using an analytic rubric uses the scores of each of the individual criteria.

7.1.2. Holistic Rubrics

A holistic rubric evaluates on a single scale with all the performance criteria being included in the evaluation together. The rater then assigns a single score (usually on a scale

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of 1 to 4 or 1 to 6) indicating an overall judgment of the student performance. Thus, the entire performance of a student is marked by a single value on the scale.

8. Rubrics based Assessment Methodology

An example list of different tools and techniques for assessing student's performance may be represented as shown in Tables 1, 2 and 3 [48].

Table 1. Assessment tools and techniques

Asst. #	Assessment Method	Particulars
Asst. 1.0	**Direct Assessment**	
Asst. 1.1	**Continuous Assessment**	
Asst. 1.1.1	Multiple Choice Questions (MCQ) (Class Test)	To test the coverage of subject
Asst. 1.1.2	Short Answer type Questions (SAQ) (Class Test)	To test the concept and ability of analysis
Asst. 1.1.3	Problem based Questions (Class Test)	To test application of relevant theory
Asst. 1.1.4	Designing based Questions (Class Test)	To judge ability to apply theory in synthesizing feasible solution
Asst. 1.1.5	Open Ended Realistic Questions (Class Test)	To judge the ability to analyze, investigate and evaluate
Asst. 1.1.6	Assignments (Home Assignment)	To judge learning habit, ability of technical report writing, teamwork
Asst. 1.1.7	Technical Quiz (Written/Verbal)	To judge subject coverage, presence of mind, learning habits, communication skills
Asst. 1.1.8	Classroom Manifestation/Seminar on pre-assigned subject topics/chosen topics	To judge understanding, communication skill and confidence level
Asst. 1.1.9	Class performance (interaction, discipline, attendance, response to instruction etc.)	To judge professional ethics, attitude
Asst. 1.1.10	Laboratory Assignments/Experiments (incl. conducting physical tests using tools and preparing lab reports)	To judge practical skills, engg. attitude,reporting skill, teamwork
Asst. 1.1.11	Micro Project (in labs) (to guide experiments, integrate result, analyze result and report)	To judge team work, process management, integrated approach

8.1. Innovative Assessment Instruments, Tools and Rubrics

Innovative assessment rubrics are developed by an educational institution to properly assess outcome based education. Every educational institution has some well defined Program Educational Objectives (PEOs) in tune with its Vision and Mission. These PEOs are basically showed by appropriately planned Program Outcomes (POs) in order to inject the substance of the Graduate Attributes (GAs), which speak to the characteristics, abilities, and understandings that the institution concurs its students ought to create during their experience with the institution. These attributes include but go beyond the disciplinary expertise or technical knowledge that has traditionally formed the core of most university courses. These Graduate Attributes as laid out by RCC Institute of Information Technology, Kolkata, India [48] are twelve in number and are listed below.

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Table 2. Assessment tools and techniques Contd...

Asst. #	Assessment Method	Particulars
Asst. 1.0	**Direct Assessment**	
Asst. 1.1	**Continuous Assessment**	
Asst. 1.1.12	Minor & Major Projects (incl. selecting project thru literature survey, selecting tools/platform, requirement analysis, fixing specification, designing, developing (writing codes), creating UI and finding limitations/bugs)	To judge skill of problem analysis, system study, investigation of soln. & tools, designing /developing /creative ability, communication skill, teamwork, mgmt. & leadership Steps of allocating and developing the project: 1. Supervisors float Projects 2. Students opts Projects 3. Project Coordinator(s) allocates Projects to group of students by resolving constraints 4. Project synopsis submitted by students and corrected/approved by Supervisors 5. Literature Survey and existing system study 6. Design of algorithms, schemas and prototype 7. Presentation of design/prototype and adjust/augment the design or functionalities through supervisor and other faculty feedback 8. Complete Project (system development with GUI or program execution and output analysis) with guidance of supervisor 9. Present the complete project 10. Submit Project Report

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Table 3. Assessment tools and techniques Contd...

Asst. #	Assessment Method	Particulars
Asst. 1.0	**Direct Assessment**	
Asst. 1.1	**Continuous Assessment**	
Asst. 1.2	Terminal Test (Semester Examination)	End of term University Exams to assess grades (CGPA, YGPA, DGPA)
Asst. 1.2.1	Written Exams (incl. Multiple Choice Questions, Short and Long Answer type Questions, Numerical Problems & Design Problems)	To be assessed by University appointed Examiners
Asst. 1.2.2	Laboratory Exams (to guide certain experiments, tool based reports and assignments the procedure, results etc. followed by Viva Voce)	To be assessed by subject teacher under the supervision of University appointed Examiner
Asst. 1.2.3	Seminar & Project Presentation (Minor & Major Project) incl. submission of Project Report	To be assessed by project supervisor and University appointed Examiner
Asst. 1.2.4	Grand Viva (on professional core subjects)	To judge knowledge in core subjects and assessed by subject teachers
Asst. 1.2.5	Group Discussion (on different technical issues)	To judge presentation and communication skill, leadership, professional ethics, social/technical awareness
Asst. 2.0	**Indirect Assessment**	
Asst. 2.0.1	Perception of Performance in Co-Curricular and Extra-Curricular Activities	May be judged based on declared criteria as number of events participated in college/inter-college/state/national level, number of awards received etc.
Asst. 2.0.2	Self Assessment by Students	Applied where student performance cannot be judged directly by the assessor

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1. **(KB)** A knowledge base for engineering: A capacity to show skill in university level subjects like natural sciences, mathematics, engineering fundamentals, and specific engineering knowledge considered to be proper for the program.
2. **(PA)** Problem analysis: An ability to acquire relevant knowledge and skills to analyze and solve complex engineering problems.
3. **(Inv.)** Investigation: A capacity to carry on examinations of complex issues by utilizing proper tests, investigation, and translation of information and amalgamation of the data to infer legitimate ends thereof.
4. **(Des.)** Design: A capacity to concoct plan answers for unpredictable, open-ended engineering problems that line up with standards for wellbeing and dangers, appropriate principles, and monetary, ecological, social and cultural contemplations.
5. **(Tools)** Use of engineering tools: A capacity to apply and adjust appropriate techniques and modern engineering tools to address a range of engineering activities, from simple to complex.
6. **(Team)** Individual and teamwork: A capacity to work successfully in a multi-disciplinary group either as a member or as a leader.
7. **(Comm.)** Communication skills: A capacity to appreciate and impart complex engineering ideas inside the profession and with society everywhere by the assistance of compelling announcing and plan documentation.
8. **(Prof.)** Professionalism: An ability to achieve the highest level of professionalism in the society.
9. **(Impacts)** Impact of engineering on society and the environment: A capacity to comprehend the cultural and ecological parts of engineering exercises to accomplish a sustainable effect.
10. **(Ethics)** Ethics and equity: A capacity to keep proficient morals, responsibility, and value.
11. **(Econ.)** Economics and project management: A capacity to absorb the financial and business impacts into the act of engineering.
12. **(LL)** Life-long learning: A capacity to motivate towards life-long continuous learning and upgradation in order to maintain competence and skills in this ever changing scenario.

A set of twelve similar POs exist in line with the GAs. Further into the abstraction level, these POs are related/mapped to COs (course outcomes) for every course in the offering to elicit the knowledge-base infused in the students after imparting the courses.
Individual portfolios of students are used for record keeping and compilation of final assessment result to be certified by the University. The sum of accomplishment of POs (& PEOs) are judged before the issuance of certificates.

9. Quantitative Assessment of Rubrics

It is evident from the different scoring procedures adopted for the assessment of rubrics that the assessment mechanism is more of a subjective one than an objective one. This is essentially due to the fact that the performance measures used for the purpose are mapped on a scale of 1 to 10, which makes it inherently vague and uncertain. Moreover, the assessment is guided by the frame of mind of the rater and his abstract understanding of the performance. Hence, it is aptly clear that several uncertain factors induced by human reasoning (the rater) comes into play during the assessment process. As a result, the assessment often remains far from being absolute and universal.
In order to overcome these limitations, a novel quantitative assessment method is proposed in this chapter which takes into cognizance the inherent uncertainties in the human thought process. In fact, the thought process can be modeled in the form of a fuzzy reasoning so as to elicit more appropriate and quantitative response from the assessment process.

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9.1. Fuzzy Modeling of Assessment Rubrics

The B. Tech. Program in Information Technology (syllabus prescribed by Maulana Abul Kalam Azad University of Technology, Kolkata, India, see https://makautwb.ac.in/ and designed by the Department of Information Technology of RCC Institute of Information Technology [48]) has set down twelve Program Outcomes (POs) relevant to the Course Outcomes of different courses offered by the Department, corresponding to the twelve graduate attributes as mentioned in Section 8.1. These are as follows.

1. **PO1** pertaining to Engineering Knowledge.
2. **PO2** pertaining to Problem Analysis.
3. **PO3** pertaining to Conducting of Investigations.
4. **PO4** pertaining to Design/Development of Solutions.
5. **PO5** pertaining to Modern Tool Usage.
6. **PO6** pertaining to Individual skills and Teamwork.
7. **PO7** pertaining to Communication.
8. **PO8** pertaining to the Professionalism of Engineer in the society.
9. **PO9** pertaining to Environment and sustainability.
10. **P10** pertaining to Ethics.
11. **PO11** pertaining to Project Management and Finance.
12. **PO12** pertaining to Life-long learning.

In order to model the assessment process as a fuzzy model, we put forward the mapping scenario of the course outcomes (COs) of the course titled **Major Project: IT892** with the relevant program outcomes (POs) **[PO1, PO2, PO3, PO4, PO5, PO6, PO8, PO9, PO10 and PO11]** of the program offering the course in Table 4 [48].

Table 4. Example mapping of COs with POs

S. No	Course Code	Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
1	Major Project (IT892)	1. Map theoretical knowledge into practical implementation.	S	M	S	M	S							
		2. Compose and comprehend documentation of a standard project work.										S	M	
		3. Develop team spirit and leadership qualities.									S	S		
		4. Get a brief exposure of doing a cutoff time explicit software project prior to joining to industry/higher studies.						S		M			S	

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Given the subjective nature of human reasoning, it is not possible to draw any quantitative correspondence/mapping between the POs and COs by using conventional ranking systems. Since human reasoning comes in to play in the mapping mechanism, the correspondence/mapping is often vague and imprecise. Hence, a proper fuzzy modeling of the mapping mechanism would be able to handle the underlying vagueness/imprecision. Based on the fuzzy nature of human reasoning, the mapping can be fuzzified into three fuzzy levels identified by three grades of membership in the form of **S**trong, **M**edium and **W**eak. Thus, this fuzzification procedure ensures the maximum total response to be 1.0 (0.5+0.3+0.2). A flow diagram of the proposed fuzzy model for the purpose of quantitative evaluation of the assessment rubrics based scores, is shown in Figure 4.
As shown in Figure 4, the individual N number of POs (PO 1, PO 2, PO 3, ... PO N) in the **Program Outcomes** module for a particular student are being fed to the corresponding single input fuzzifiers (FM 1, FM 2, FM 3, ... FM N) in the **Fuzzifier** module resulting in fuzzified POs. Subsequently, the assessment rubrics based scores ($Score$ 1, $Score$ 2, $Score$ 3, ... $Score$ N) are multiplied by the respective fuzzified POs and collated followed by averaging in the **Averaging** module. Finally, the averaged POs yield the desired %PO *attained* for the student.

9.1.1. Assessment Components and Tools

In order to have a quantitative evaluation of a student's performance, one needs to identify the appropriate assessment components and tools from the exhaustive list presented in Table 1. The two major components required for the assessment of a student's performance as far as the course titled **Major Project: IT892** is concerned are (i) Continuous Assessment and (ii) Project Presentation as shown in Table 5. The corresponding assessment methods/tools and their mapping with the relevant POs along with the respective mapping fuzzy levels are also shown in the Table 5 [48].

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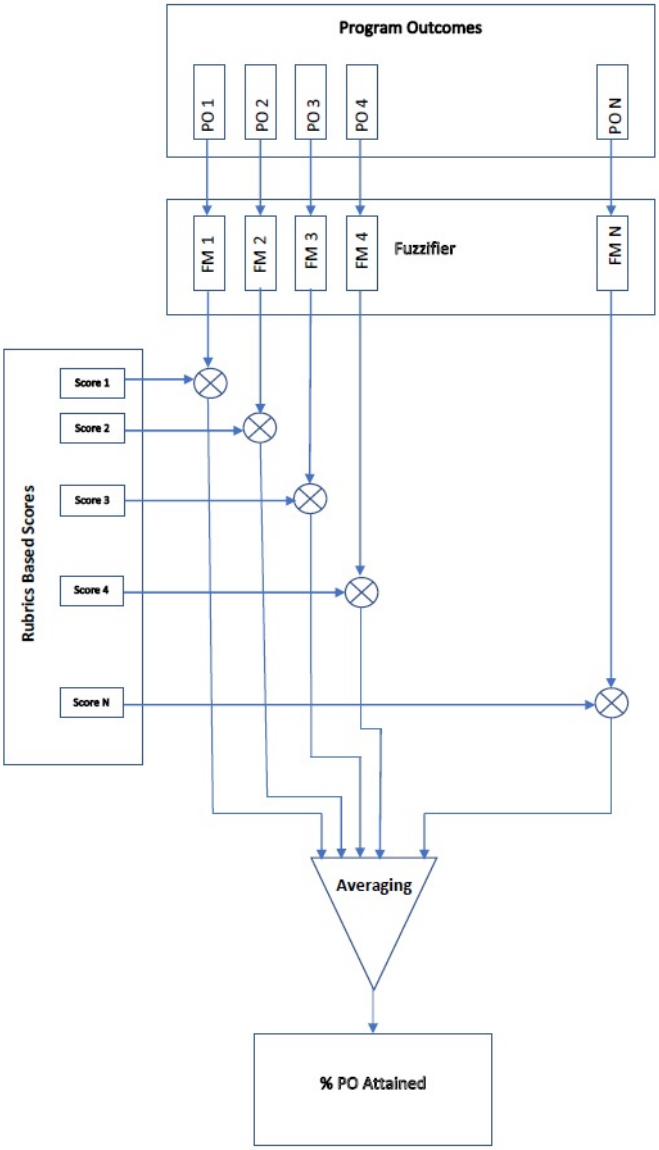

Figure 4. Flow Diagram

Table 5. Selection of Assessment Components and Tools for IT892

Evaluation Tools Component	#	Method/Element	PO1	PO2	PO3	PO4	PO5	PO6	PO8	PO9	PO10	PO11
Cont. Assmt.	1.1.12	Literature Survey	S			M						M
		Study, Investigation & Requirement Analysis	S	S		S		M				M
		Planning & Designing, Creative Ability		M	S							M
		Building up Solution/System			S		M	M				M
		Application of latest Technology /Concept	S				S					M
		Testing & Debugging		S	S	M	S					M
		Documentation & Report									S	S
		Leadership & Teamwork							M	S		S
		Regularity							S			
Project Presentation	1.2.3	Nature of Technical Content, Planning & Adherence to Context, Demo of Prototype	M		S		M			W	S	S
		Depth of Understanding & Preparation	S	M						M		
		Confidence, Body Language & Communication Skill									S	W
		Q/A, Manners, Interaction	S	M					W	W	S	
		Assessment by University Examiner	S	M	S	S	S	S	M	M	S	
	2.2.5	Faculty and Staff Satisfaction Survey	S		M					M	S	
	2.2.5	Employer Survey	M		S		S		W	M	S	S

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9.1.2. Assessment Rubrics based Scoring

A student can be graded based on his/her levels of competency to fulfill each and every method of the assessment components. These levels of competency of a student for each method can be assessed on a scale of 1 (Poor) to 4 (Excellent) with 2 (Developing) and 3 (Good) being the intermediate levels. This scale of grading is referred to as the grading criteria. The qualitative performance indices for each grading criteria corresponding to each method is generally expressed in linguistic terms instead of deterministic values. These qualitative indices are referred to as the Rubrics for the assessment of the student's performance and the grading criteria are the Rubrics based scoring criteria. Tables 6, 8 and 9 [48] enlist the different types of Rubrics corresponding to four assessment tools (two for direct assessment and two for indirect assessment) viz., Continuous Assessment (Assessment no. 1.1.12), Project Presentation (Assessment no. 1.2.3), Teaching and non-teaching staffs Satisfaction Survey (Assessment No. 2.2.5) and Employer Survey (Assessment No. 2.2.1).

Table 6. Assessment Rubrics 1 for Continuous Assessment Component of IT892

Assessment Tools		**Grading Criteria**			
Method/Element	**#**	**Poor (Score – 1)**	**Developing (Score – 2)**	**Good (Score – 3)**	**Excellent (Score – 4)**
Research & Literature Survey	1.1.12	Does not gather any information on the topic	Gathers very limited information on the topic	Gathers some basic and related information	Gathers a great deal of relevant information
Study, Investigation & Requirement Analysis		Requests each other individual to clarify the project without thinking or studying	Realizes the problem, studies similar systems but cannot contribute to requirement analysis without guidance	Realizes the problem; covers requirement analysis plus basic documentation (SRS)	Leads in identifying the salient requirements; adds additional features, fine tunes and standardizes documentation (SRS)
Planning & Designing Schema/Algorithm, Creative Ability		No contribution in planning & designing	Requires guidance to plan and design effectively	Contributes to planning and makes a viable design	Plans the solution effectively with innovative ideas and efficient design
Developing a Solution/System/Prototype/GUI		Poor IT skill - unable to build modules	Tries to develop few case specific modules	Develops some generic modules with higher coding complexity, attempts GUI	Develops critical mozdules & GUI with less complexity, optimizes them – ensures adherence to SRS

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Table 7. Assessment Rubrics 2 for Continuous Assessment Component of IT892

Assessment Tools		**Grading Criteria**			
Method/Element	**#**	**Poor (Score – 1)**	**Developing (Score – 2)**	**Good (Score – 3)**	**Excellent (Score – 4)**
Application of latest Technology /Concept		Poor IT skill, also reluctant to learn new technology/concepts	Conceptually weak, aware of some techniques but cannot apply without guidance	Has great technical knowledge - applies some, learns new techniques	Integrates and utilizes powerfully new strategies/idea, adapts fast, guides others
Testing & Debugging		Poor IT skill – unable to test and debug	Tests but unable to debug	Contributes fairly – debugs/repairs most errors	Designs test cases, tests and debugs critical errors
Documentation & Report		Poor contribution in documentation and report preparation	Helps in documenting various stages however needs report writing skills, plays supportive role	Explicates the basic structure of project report, checks documentation standard	Does major portion of report writing, makes the report technically comprehensive and guarantees adherence to standards
Leadership & Teamwork		Does not play out any duties assigned to team role	Develops minimal duties, cares for other team members	Develops nearly all duties, helps other team members	Develops all duties, takes additional responsibilities, guides other members and leads the team
Regularity		Irregular	Fairly regular	Quite regular	Very much regular

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Table 8. Assessment Rubrics 3 for Project Presentation Component of IT892

Assessment Tools		**Grading Criteria**			
Method/Element	**#**	**Poor (Score – 1)**	**Developing (Score – 2)**	**Good (Score – 3)**	**Excellent (Score – 4)**
Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	1.2.3	Least contribution in making the prototype and the ppt, Poor quality, Negligible part played in giving the presentation and the demo	Some contribution in making the prototype and the ppt, Average quality, Fair part played in giving the presentation and the demo	Significant contribution in making the prototype and the ppt, Good quality, Active part played in giving the presentation and the demo	Maximum contribution in making the prototype and the ppt, Best quality, Preceding part played in giving the presentation and the demo
Depth of Understanding and Preparation		Poor understanding	Does not understand all modules	Understands working of all modules but lacks knowledge about reason and remedies of project limitation;	Clearly understands working of all modules, limitations and possible remedies; thorough preparation
Body Language, Confidence & Communication Skill		Unimpressive reflecting lack of confidence, low voice, poor linguistic skills	Starting well but frequently faltering and losing confidence, medium voice , limited linguistic skills	Acceptable but does not make impact on the audience, good linguistic skill but often fails to communicate effectively, acceptable voice,	Attracts attention and makes the demo lively, applies the art of effective communication, strong voice, strong linguistic skill
Q&A and interaction, Manners		Wrong response or explanation, ill-mannered	Sketchy explanation, skips complicated parts, needs support, lacking manners	Good explanation at some Qs, helps other members while answering, good manners	Clear explanation with examples, volunteers answering hard/critical Qs, well mannered

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Table 9. Assessment Rubrics 4 for Indirect Assessment of IT892

Assessment Tools		**Grading Criteria**			
Method/Element	**#**	**Poor (Score – 1)**	**Developing (Score – 2)**	**Good (Score – 3)**	**Excellent (Score – 4)**
Assessment by University Examiner		$\leq$ 40%	>40% - 60%	>60% - 80%	>80%
Faculty and Staff Satisfaction Survey	2.2.5	Basically poor knowledge understanding & programming skill, careless approach in team, weak soft skill	Conceptually weak, needs guidance in programming, plays some role in team, lacks in soft skill	Has preliminary knowledge, good programming skill, report writing skill and soft skill. lacks in technical depth and leadership, hard worker	Has solid knowledge, can manage any type of questions at any difficulty level with utmost confidence, has excellent report writing and soft skill and leadership quality, good finisher
Employer Survey	2.2.1	Need proficient ability and disposition, got poor exposure in SDLC	Extension for development of professional skill and attitude, lacks exposure in all stages of SDLC	Good professional skill and attitude, good exposure in SDLC stages, lacks leadership and technical depth	Excellent professional skill and attitude, has leadership quality and technically sound, proficient in conducting all stages of SDLC

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9.1.3. Fuzzy Scoring Mechanism

After having identified the different fuzzy mapping levels for the CO-PO mapping as shown in Table 5, the next step involves a fuzzy scoring mechanism to derive the quantitative performance of the students based on the fuzzy membership values coupled with the Assessment Rubrics based scoring as given in Tables 6, 8 and 9.
The selection of an appropriate fuzzy membership function for the individual fuzzifiers as shown in Figure 4 is a challenging proposition and still remains an open problem in the scientific research community. Most of the methods reported in the literature have resorted to the system knowledge for a proper choice of the membership function. Although the Triangular fuzzy membership function is the simplest one and is also computationally faster than other membership functions due to its linear nature, yet it often fails to approximate and model the behaviour of complex and non-linear systems. On the other hand, the Open Right Sigmoidal and Gaussian fuzzy membership functions are non-linear in nature and hence are both computationally intensive. However, these non-linear membershio functions are more capable of modeling complex and non-linear systems. Due to the absence of any yardstick for choosing the appropriate fuzzifier, we have chosen and compared three different fuzzifiers in the form of Open Right Sigmoidal fuzzifier, Gaussian fuzzifier and Triangular fuzzifier to model the rubrics based assessment system.
Moreover, there being no proven strategy for selecting the degrees of membership of the different fuzzy levels in a fuzzifier (excluding evolutionary fuzzy systems which is beyond the scope of the present work and which may be considered as a future work), we have selected the fuzzy memberships/weights to be assigned to the respective fuzzy levels of the relevant POs heuristically. We have experimented with several combinations of the fuzzy memberships and arrived at the following combination which yielded the best possible outcome.

1. For the Open Right Sigmoidal fuzzifier, the fuzzy memberships/weights assigned to the respective fuzzy levels of the relevant POs are selected as $W_{\mathbf{S}} = 0.5$ [top of the Sigmoidal membership], $W_{\mathbf{M}} = 0.3$ [neck of the Sigmoidal membership] and $W_{\mathbf{W}} = 0.2$ [base of the Sigmoidal membership] indicated by the fuzzy membership based weightage of the assessment rubrics based scores. Hence, the score for the i^{th} PO_i corresponding to a particular method is given by the product of the fuzzy membership either $W_{\mathbf{S}}$ or $W_{\mathbf{M}}$ or $W_{\mathbf{W}}$) as applicable from the mapping given in Table 5 and the assessment rubrics based score derived from Tables 6, 8 and 9 [48].
2. Similarly, for the Gaussian fuzzifier (considering a unform Gaussian distribution), the fuzzy memberships/weights assigned to the respective fuzzy levels of the relevant POs are selected as $W_{\mathbf{M}} = 0.8$ [top of the Gaussian membership], $W_{\mathbf{S}} = 0.1$ [neck of the Gaussian membership] and $W_{\mathbf{W}} = 0.1$ [base of the Gaussian membership].
3. The corresponding fuzzy memberships/weights selected for the Triangular fuzzifier are $W_{\mathbf{M}} = 1$ [peak of the Triangular membership], $W_{\mathbf{S}} = 0$ [left base of the Triangular membership] and $W_{\mathbf{W}} = 0$ [right base of the Triangular membership].

Tables 10 and 11 [48] show an example listing of the weighted evaluation using the Open Right Sigmoidal fuzzifier.
The weighted score (WS) for the i^{th} PO is obtained by the following expression.

$$WS_{PO_i} = \frac{\sum_j^N W_{E_j} \times Score_j}{\sum_j^N W_{E_j}} \tag{6}$$

where, W_{E_j} is the fuzzy weighted evaluation for the j^{th} method/element, $Score_j$ is the assessment rubrics based score for the j^{th} method/element and $j = 1, 2, 3, \ldots, N$ represents the number of mapped methods/elements.

Table 10. Fuzzy Scoring Mechanism for IT892 using Open Right Sigmoidal Fuzzifier

Score	Weighted Evaluation (W_E) of POs ($W_S = 0.5$ | | $W_M = 0.3$ | | $W_W = 0.2$)									
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO8**	**PO9**	**PO10**	**PO11**
Score	0.5 × Score			0.3 × Score						0.3 × Score
Score	0.5 × Score	0.5 × Score		0.5 × Score		0.3 × Score				0.3 × Score
Score		0.3 × Score	0.5 × Score							0.3 × Score
Score			0.5 × Score		0.3 × Score	0.3 × Score				0.3 × Score
Score	0.5 × Score				0.5 × Score					0.3 × Score
Score		0.5 × Score	0.5 × Score	0.3 × Score	0.5 × Score					0.3 × Score
Score									0.5 × Score	0.5 × Score
Score							0.3 × Score	0.5 × Score		0.5 × Score
Score							0.5 × Score			

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Table 11. Fuzzy Scoring Mechanism for IT892 Contd...

Score	**Weighted Evaluation (W_E) of POs ($W_S = 0.5$ | | $W_M = 0.3$ | | $W_W = 0.2$)**									
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO8**	**PO9**	**PO10**	**PO11**
Score	0.3 × Score		0.5 × Score		0.3 × Score			0.2 × Score	0.5 × Score	0.5 × Score
Score	0.5 × Score	0.3 × Score						0.3 × Score		
Score									0.5 × Score	0.2 × Score
Score	0.5 × Score	0.3 × Score					0.2 × Score	0.2 × Score	0.5 × Score	
Score	0.5 × Score	0.3 × Score	0.5 × Score	0.5 × Score	0.5 × Score	0.5 × Score	0.3 × Score	0.3 × Score	0.5 × Score	
Score	0.5 × Score		0.3 × Score					0.3 × Score	0.5 × Score	
Score	0.3 × Score		0.5 × Score		0.5 × Score		0.2 × Score	0.3 × Score	0.5 × Score	0.5 × Score
WS	**Total/4.1**	**Total/2.2**	**Total/3.3**	**Total/1.6**	**Total/2.6**	**Total/1.1**	**Total/1.5**	**Total/2.1**	**Total/3.5**	**Total/4.0**
% PO attained	**(WS/4)×100**	**(WS/4)×100**	**(WS/4)×100**	**(WS/4)×100**	**(WS/4)×100**	**(WS/4)×100**	**(WS/4)×100**	**(WS/4)×100**	**(WS/4)×100**	**(WS/4)×100**

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Thus, the weighted score (WS) for $PO1$ for the Open Right Sigmoidal fuzzifier (from Tables 10 and 11 [48]) comes out to be

$$\frac{\textbf{Total}}{\textbf{(0.5+0.5+0.5+0.3+0.5+0.5+0.5+0.5+0.3)=4.1}}$$

where, *Total* is the sum of all assessment rubrics based scores for **PO1**. Similarly, the weighted scores for all other relevant POs can be calculated.
Finally, the % of **PO** attainment is evaluated by averaging the weighted score for a particular **PO** over the number (n) of relevant assessment tools as

$$\%\ PO_i = \frac{WS_{PO_i}}{n} \times 100 \tag{7}$$

It is evident from Tables 6, 8 and 9 that the number (n) of the assessment tools under consideration is equal to 4 (1.1.2, 1.2.3, 2.2.5, 2.2.1). Hence, % of all the **POs** attained are obtained by averaging the weighted scores of each **PO** by $n = 4$ as shown in Tables 10 and 11.
Similar expressions can be obtained for the Gaussian and Triangular fuzzifiers as well. Thus, it is possible to arrive at a quantitative evaluation of the attainment of **POs** for a student using a Gaussian fuzzifier based scoring mechanism.

9.1.4. Case Studies on Indian Scenario

The proposed fuzzy based quantitative approach has been applied to the different courses under the B. Tech. program of Information Technology of RCC Institute of Information Technology [48] affiliated to Maulana Abul Kalam Azad University of Technology, Kolkata, India. It has been found to evaluate the students' performance quantitatively as regards to their **PO** attainment quite successfully. As example case studies, the performances of two different students (Mr. Tom Haykins and Mr. Russel Hilfiger) enrolled in the courses titled **Major Project: IT892** and **Design Lab: IT 981** (with an additional **PO12**) are demonstrated with respect to the % attainment of relevant **POs** for the two courses using the Open Right Sigmoidal, Triangular and Gaussian fuzzifiers. The **Score** value ranges from **1** to **4**. Figures 5 and 6 show the performance (% attainment of **POs**) for Mr. Tom Haykins for **Major Project: IT892** and **Design Lab: IT 891**, respectively using the Open Right Sigmoidal fuzzifier. Figures 7 and 8 show the performance (% attainment of **POs**) for Mr. Russel Hilfiger for **Major Project: IT892** and **Design Lab: IT 891**, respectively using the Open Right Sigmoidal fuzzifier.
Figures 9 and 10 show the performance (% attainment of **POs**) for Mr. Tom Haykins for **Major Project: IT892** and **Design Lab: IT 891**, respectively using the Triangular fuzzifier. Figures 11 and 12 show the performance (% attainment of **POs**) for Mr. Russel Hilfiger for **Major Project: IT892** and **Design Lab: IT 891**, respectively using the Triangular fuzzifier. Figures 13 and 14 show the performance (% attainment of **POs**) for Mr. Tom Haykins for **Major Project: IT892** and **Design Lab: IT 891**, respectively using the Gaussian fuzzifier. Figures 15 and 16 show the performance (% attainment of **POs**) for Mr. Russel Hilfiger for **Major Project: IT892** and **Design Lab: IT 891**, respectively using the Gaussian fuzzifier.
In addition, the performances of these two students have also been assessed using the normal conventional Rubrics based assessment. Figures 17 and 18 show the performance (% attainment of **POs**) for Mr. Tom Haykins for **Major Project: IT892** and **Design Lab: IT 891**, respectively using normal Rubrics based assessment scores. Figures 19 and 20 show the performance (% attainment of **POs**) for Mr. Russel Hilfiger for **Major Project: IT892** and **Design Lab: IT 891**, respectively using normal Rubrics based assessment scores.

Figure 5. Fuzzy scoring based assessment of Mr. Tom Haykins for IT892 with Open Right Sigmoidal Membership

Paper Name: Major Project			Paper Code: IT 892									Session: 2014 - 2015
Name:		Tom Haykins		Roll No.:		201402009						
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	4	2			1.2						1.2
		Study, Investigation & Requirement Analysis	3	1.5	1.5		1.5		0.9				0.9
		Planning & Designing, Creative Ability	3		0.9	1.5							0.9
		Developing Solution/System	4			2		1.2	1.2				1.2
		Application of latest Technology /Concept	4	2				2					1.2
		Testing & Debugging	4		2	2	1.2	2					1.2
		Documentation & Report	3									1.5	1.5
		Leadership & Teamwork	2							0.6	1		1
		Regularity	2							1			
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	0.6		1		0.6			0.4	1	1
		Depth of Understanding & Preparation	3	1.5	0.9						0.9		
		Body Language, Confidence & Communication Skill	2									1	0.4
		Q/A, Interaction, Manners	2	1	0.6					0.4	0.4	1	
		Assessment by University Examiner	3	1.5	0.9	1.5	1.5	1.5	1.5	0.9	0.9	1.5	
Indirect	2.2.5	Faculty and Staff Satisfaction Survey	2	1		0.6					0.6	1	
	2.2.6	Employer Survey	1	0.3		0.5		0.5		0.2	0.3	0.5	0.5
		Weighted Score (WS)		2.78	3.09	2.76	3.38	3.00	3.27	2.07	2.14	2.14	2.75
		%PO attained		69.51	77.27	68.94	84.38	75.00	81.82	51.67	53.57	53.57	68.75

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Figure 6. Fuzzy scoring based assessment of Mr. Tom Haykins for IT891 with Open Right Sigmoidal Membership

Paper Name: Design Lab			Paper Code: IT 891										Session: 2014 - 2015
Name:	Tom Haykins		Roll No.:	201402009									
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11	PO12
Design Lab (Continuous Assessment)	1.1.12	Research & Literature Survey	3	1.5			0.9						0.9	0.9
		Study, Investigation & Requirement Analysis	3	1.5	1.5		1.5		0.9				0.9	0.9
		Planning & Designing, Creative Ability	2		0.6	1							0.6	0.6
		Developing Solution/System	2			1		0.6	0.6				0.6	0.6
		Application of latest Technology /Concept	2	1				1					0.6	0.6
		Testing & Debugging	3		1.5	1.5	0.9	1.5					0.9	
		Documentation & Report	2									1	1	
		Leadership & Teamwork	4							1.2	2		2	
		Regularity	2							1				
Terminal Test/ Design Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	3	0.9		1.5		0.9			0.6	1.5	1.5	0.6
		Depth of Understanding & Preparation	3	1.5	0.9						0.9			0.9
		Body Language, Confidence & Communication Skill	3									1.5	0.6	
		Q/A, Interaction, Manners	3	1.5	0.9					0.6	0.6	1.5		
		Assessment by University Examiner	3	1.5	0.9	1.5	1.5	1.5	1.5	0.9	0.9	1.5		0.6
Indirect	2.2.5	Faculty and Staff Satisfaction Survey	2	1		0.6					0.6	1		0.6
	2.2.6	Employer Survey	2	0.6		1		1		0.4	0.6	1	1	1
		Weighted Score (WS)		2.68	2.86	2.45	3.00	2.50	2.73	2.73	2.95	2.57	2.65	1.83
		%PO attained		67.07	71.59	61.36	75.00	62.50	68.18	68.33	73.81	64.29	66.25	45.63

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Figure 7. Fuzzy scoring based assessment of Mr. Russel Hilfiger for IT892 with Open Right Sigmoidal Membership

Paper Name: Major Project			Paper Code: IT 892									Session: 2014 - 2015
Name:		Russel Hilfiger		Roll No.:		201402011						
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	3	1.5			0.9						0.9
		Study, Investigation & Requirement Analysis	3	1.5	1.5		1.5		0.9				0.9
		Planning & Designing, Creative Ability	2		0.6	1							0.6
		Developing Solution/System	2			1		0.6	0.6				0.6
		Application of latest Technology /Concept	2	1				1					0.6
		Testing & Debugging	2		1	1	0.6	1					0.6
		Documentation & Report	2									1	1
		Leadership & Teamwork	4							1.2	2		2
		Regularity	2							1			
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	0.6		1		0.6			0.4	1	1
		Depth of Understanding & Preparation	3	1.5	0.9						0.9		
		Body Language, Confidence & Communication Skill	2									1	0.4
		Q/A, Interaction, Manners	3	1.5	0.9					0.6	0.6	1.5	
		Assessment by University Examiner	2	1	0.6	1	1	1	1	0.6	0.6	1	
Indirect	2.2.5	Faculty and Staff Satisfaction Survey	2	1		0.6					0.6	1	
	2.2.6	Employer Survey	2	0.6		1		1		0.4	0.6	1	1
		Weighted Score (WS)		2.49	2.50	2.00	2.50	2.00	2.27	2.53	2.71	2.14	2.40
		%PO attained		62.20	62.50	50.00	62.50	50.00	56.82	63.33	67.86	53.57	60.00

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Figure 8. Fuzzy scoring based assessment of Mr. Russel Hilfiger for IT891 with Open Right Sigmoidal Membership

Paper Name: Design Lab			Paper Code: IT 891										Session: 2014 - 2015
Name:	Russel Hilfiger		Roll No.:	201402011									
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11	PO12
Design Lab (Continuous Assessment)	1.1.12	Research & Literature Survey	2	1			0.6						0.6	0.6
		Study, Investigation & Requirement Analysis	3	1.5	1.5		1.5		0.9				0.9	0.9
		Planning & Designing, Creative Ability	2		0.6	1							0.6	0.6
		Developing Solution/System	2			1		0.6	0.6				0.6	0.6
		Application of latest Technology /Concept	2	1				1					0.6	0.6
		Testing & Debugging	3		1.5	1.5	0.9	1.5					0.9	
		Documentation & Report	2									1	1	
		Leadership & Teamwork	4							1.2	2		2	
		Regularity	2							1				
Terminal Test/ Design Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	0.6		1		0.6			0.4	1	1	0.4
		Depth of Understanding & Preparation	3	1.5	0.9						0.9			0.9
		Body Language, Confidence & Communication Skill	3									1.5	0.6	
		Q/A, Interaction, Manners	3	1.5	0.9					0.6	0.6	1.5		
		Assessment by University Examiner	3	1.5	0.9	1.5	1.5	1.5	1.5	0.9	0.9	1.5		0.6
Indirect	2.2.5	Faculty and Staff Satisfaction Survey	2	1		0.6					0.6	1		0.6
	2.2.6	Employer Survey	2	0.6		1		1		0.4	0.6	1	1	1
			Weighted Score (WS)	2.49	2.86	2.30	2.81	2.38	2.73	2.73	2.86	2.43	2.45	1.70
			%PO attained	62.20	71.59	57.58	70.31	59.62	68.18	68.33	71.43	60.71	61.25	42.50

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Figure 9. Fuzzy scoring based assessment of Mr. Tom Haykins for IT892 with Triangular Membership

Paper Name: Major Project			Paper Code: IT 892									Session: 2014 - 2015
Name:	Tom Haykins		Roll No.:	201402009								
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	4			4							4
		Study, Investigation & Requirement Analysis	3						3				3
		Planning & Designing, Creative Ability	3		3								3
		Developing Solution/System	4					4	4				4
		Application of latest Technology /Concept	4										4
		Testing & Debugging	4				4						4
		Documentation & Report	3										
		Leadership & Teamwork	2							2			
		Regularity	2										
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	2				2					
		Depth of Understanding & Preparation	3		3						3		
		Body Language, Confidence & Communication Skill	3										
		Q/A, Interaction, Manners	3		3								
		Assessment by University Examiner	3		3					3	3		
	2.2.5	Faculty and Staff Satisfaction Survey	2			2					2		
	2.2.5	Employer Survey	1	1							1		
		Weighted Score (WS)		1.50	3.00	3.00	4.00	3.00	3.50	2.50	2.25	NULL	3.67
		%PO attained		37.50	75.00	75.00	100.00	75.00	87.50	62.50	56.25	NULL	91.67

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Figure 10. Fuzzy scoring based assessment of Mr. Tom Haykins for IT891 with Triangular Membership

Paper Name: Major Project			Paper Code: IT 891										Session: 2014 - 2015	
Name:		Tom Haykins		Roll No.:		201402009								
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11	PO 12
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	4				4						4	4
		Study, Investigation & Requirement Analysis	3						3				3	3
		Planning & Designing, Creative Ability	3		3								3	3
		Developing Solution/System	4					4	4				4	4
		Application of latest Technology /Concept	4										4	4
		Testing & Debugging	4				4						4	
		Documentation & Report	3											
		Leadership & Teamwork	2							2				
		Regularity	2											
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	2				2						
		Depth of Understanding & Preparation	3		3						3			3
		Body Language, Confidence & Communication Skill	3											
		Q/A, Interaction, Manners	3		3									
		Assessment by University Examiner	3		3					3	3			
	2.2.5	Faculty and Staff Satisfaction Survey	2			2					2			2
	2.2.5	Employer Survey	1	1							1			
Weighted Score (WS)				1.50	3.00	2.00	4.00	3.00	3.50	2.50	2.25	NULL	3.67	3.29
%PO attained				37.50	75.00	50.00	100.00	75.00	87.50	62.50	56.25	NULL	91.67	82.14

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Figure 11. Fuzzy scoring based assessment of Mr. Russel Hilfiger for IT892 with Triangular Membership

Paper Name: Major Project			Paper Code: IT 892									Session: 2014 - 2015
Name:	Russel Hilfiger		Roll No.:	201402011								
	#	Method/Element	Score (1–4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	3			3							3
		Study, Investigation & Requirement Analysis	3						3				3
		Planning & Designing, Creative Ability	2		2								2
		Developing Solution/System	2					2	2				2
		Application of latest Technology /Concept	2										2
		Testing & Debugging	2				2						2
		Documentation & Report	2										
		Leadership & Teamwork	4							4			
		Regularity	2										
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	2				2					
		Depth of Understanding & Preparation	3		3						3		
		Body Language, Confidence & Communication Skill	2										
		Q/A, Interaction, Manners	3		3								
		Assessment by University Examiner	2		2					2	2		
	2.2.5	Faculty and Staff Satisfaction Survey	2			2					2		
	2.2.5	Employer Survey	2	2							2		
		Weighted Score (WS)		2.00	2.50	2.50	2.00	2.00	2.50	3.00	2.25	NULL	2.33
		%PO attained		50.00	62.50	62.50	50.00	50.00	62.50	75.00	56.25	NULL	58.33

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Figure 12. Fuzzy scoring based assessment of Mr. Russel Hilfiger for IT891 with Triangular Membership

Paper Name: Major Project			Paper Code: IT 891										Session: 2014 - 2015	
Name:		Russel Hilfiger		Roll No.:		201402011								
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11	PO 12
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	3				3						3	3
		Study, Investigation & Requirement Analysis	3						3				3	3
		Planning & Designing, Creative Ability	2		2								2	2
		Developing Solution/System	2					2	2				2	2
		Application of latest Technology /Concept	2										2	2
		Testing & Debugging	2				2						2	
		Documentation & Report	2											
		Leadership & Teamwork	4							4				
		Regularity	2											
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	2				2						
		Depth of Understanding & Preparation	3		3						3			3
		Body Language, Confidence & Communication Skill	2											
		Q/A, Interaction, Manners	3		3									
		Assessment by University Examiner	2		2					2	2			
	2.2.5	Faculty and Staff Satisfaction Survey	2			2					2			2
	2.2.5	Employer Survey	2	2							2			
		Weighted Score (WS)		2.00	2.50	2.00	2.50	2.00	2.50	3.00	2.25	NULL	2.33	2.43
		%PO attained		50.00	62.50	50.00	62.50	50.00	62.50	75.00	56.25	NULL	58.33	60.71

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Figure 13. Fuzzy scoring based assessment of Mr. Tom Haykins for IT892 with Gaussian Membership

Paper Name: Major Project			Paper Code: IT 892								Session: 2014 - 2015	
Name:	Tom Haykins		Roll No.:	201402009								
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	4	3.2		0.4							0.4
		Study, Investigation & Requirement Analysis	3	2.4	2.4		2.4		0.3				0.3
		Planning & Designing, Creative Ability	3		0.3	0.3							0.3
		Developing Solution/System	4			3.2		0.4	0.4				0.4
		Application of latest Technology /Concept	4	3.2				3.2					0.4
		Testing & Debugging	4		3.2	3.2	0.4	3.2					0.4
		Documentation & Report	3									2.4	2.4
		Leadership & Teamwork	2							0.2	1.6		1.6
		Regularity	2							1.6			
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	0.2		1.6		0.2			0.2	1.6	1.6
		Depth of Understanding & Preparation	3	2.4	0.3						0.3		
		Body Language, Confidence & Communication Skill	2									1.6	0.2
		Q/A, Interaction, Manners	2	1.6	0.2					0.2	0.2	1.6	
		Assessment by University Examiner	3	2.4	0.3	2.4	2.4	2.4	2.4	0.3	0.3	2.4	
	2.2.5	Faculty and Staff Satisfaction Survey	2	1.6		0.2					0.2	1.6	
	2.2.5	Employer Survey	1	0.1		0.8		0.8		0.1	0.1	0.8	0.8
		Weighted Score (WS)		2.95	3.35	2.81	3.06	3.00	3.10	1.85	2.07	2.14	2.26
		%PO attained		73.71	83.75	70.35	76.47	75.00	77.50	46.15	51.79	53.57	56.41

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Figure 14. Fuzzy scoring based assessment of Mr. Tom Haykins for IT891 with Gaussian Membership

Paper Name: Major Project			Paper Code: IT 891										Session: 2014 - 2015
Name:		Tom Haykins		Roll No.:		201402009							
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11	PO 12
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	3	2.4			0.3						0.3	0.24
		Study, Investigation & Requirement Analysis	3	2.4	2.4		2.4		0.3				0.3	0.24
		Planning & Designing, Creative Ability	2		0.2	1.6							0.2	0
		Developing Solution/System	2			1.6		0.2	0.2				0.2	0
		Application of latest Technology /Concept	2	1.6				1.6					0.2	0.16
		Testing & Debugging	3		2.4	2.4	0.3	2.4					0.3	
		Documentation & Report	2									1.6	1.6	
		Leadership & Teamwork	4							0.4	3.2		3.2	
		Regularity	2							1.6				
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	3	0.3		2.4		0.3			0.3	2.4	2.4	0.03
		Depth of Understanding & Preparation	3	2.4	0.3						0.3			0.24
		Body Language, Confidence & Communication Skill	3									2.4	0.3	
		Q/A, Interaction, Manners	3	2.4	0.3					0.3	0.3	2.4		
		Assessment by University Examiner	3	2.4	0.3	2.4	2.4	2.4	2.4	0.3	0.3	2.4		0.24
	2.2.5	Faculty and Staff Satisfaction Survey	2	1.6		0.2					0.2	1.6		0.16
	2.2.5	Employer Survey	2	0.2		1.6		1.6		0.2	0.2	1.6	1.6	0.16
		Weighted Score (WS)		2.71	2.95	2.49	3.00	2.50	2.90	2.33	3.20	2.57	2.72	0.86
		%PO attained		67.67	73.75	62.24	75.00	62.50	72.50	58.33	80.00	64.29	67.95	21.62

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Figure 15. Fuzzy scoring based assessment of Mr. Russel Hilfiger for IT892 with Gaussian Membership

Paper Name: Major Project			Paper Code: IT 892								Session: 2014 - 2015	
Name:	Russel Hilfiger		Roll No.:	201402011								
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	3	2.4		0.3							0.3
		Study, Investigation & Requirement Analysis	3	2.4	2.4		2.4		0.3				0.3
		Planning & Designing, Creative Ability	2		0.2	0.2							0.2
		Developing Solution/System	2			1.6		0.2	0.2				0.2
		Application of latest Technology /Concept	2	1.6				1.6					0.2
		Testing & Debugging	2		1.6	1.6	0.2	1.6					0.2
		Documentation & Report	2									1.6	1.6
		Leadership & Teamwork	4							0.4	3.2		3.2
		Regularity	2							1.6			
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2	0.2		1.6		0.2			0.2	1.6	1.6
		Depth of Understanding & Preparation	3	2.4	0.3						0.3		
		Body Language, Confidence & Communication Skill	2									1.6	0.2
		Q/A, Interaction, Manners	3	2.4	0.3					0.3	0.3	2.4	
		Assessment by University Examiner	2	1.6	0.2	1.6	1.6	1.6	1.6	0.2	0.2	1.6	
	2.2.5	Faculty and Staff Satisfaction Survey	2	1.6		0.2					0.2	1.6	
	2.2.5	Employer Survey	2	0.2		1.6		1.6		0.2	0.2	1.6	1.6
		Weighted Score (WS)		2.55	2.50	2.02	2.47	2.00	2.10	2.08	3.29	2.14	2.46
		%PO attained		63.79	62.50	50.58	61.76	50.00	52.50	51.92	82.14	53.57	61.54

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Figure 16. Fuzzy scoring based assessment of Mr. Russel Hilfiger for IT892 with Gaussian Membership

Paper Name: Major Project			Paper Code: IT 891										Session: 2014 - 2015
Name:		Russel Hilfiger		Roll No.:		201402011							
	#	Method/Element	Score (1–4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11	PO 12
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	2	1.6			0.2						0.2	0.16
		Study, Investigation & Requirement Analysis	3	2.4	2.4		2.4		0.3				0.3	0.24
		Planning & Designing, Creative Ability	2		0.2	1.6							0.2	0
		Developing Solution/System	2			1.6		0.2	0.2				0.2	0
		Application of latest Technology /Concept	2	1.6				1.6					0.2	0.16
		Testing & Debugging	3		2.4	2.4	0.3	2.4					0.3	
		Documentation & Report	2									1.6	1.6	
		Leadership & Teamwork	4							0.4	3.2		3.2	
		Regularity	2							1.6				
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	3	0.3		2.4		0.3			0.3	2.4	2.4	0.03
		Depth of Understanding & Preparation	3	2.4	0.3						0.3			0.24
		Body Language, Confidence & Communication Skill	3									2.4	0.3	
		Q/A, Interaction, Manners	3	2.4	0.3					0.3	0.3	2.4		
		Assessment by University Examiner	3	2.4	0.3	2.4	2.4	2.4	2.4	0.3	0.3	2.4		0.24
	2.2.5	Faculty and Staff Satisfaction Survey	2	1.6		0.2					0.2	1.6		0.16
	2.2.5	Employer Survey	2	0.2		1.6		1.6		0.2	0.2	1.6	1.6	0.16
			Weighted Score (WS)	2.57	2.95	2.49	2.94	2.50	2.90	2.33	3.20	2.57	2.69	0.82
			%PO attained	64.22	73.75	62.24	73.61	62.50	72.50	58.33	80.00	64.29	67.31	20.44

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Figure 17. Scoring based assessment of Mr. Tom Haykins for IT892 based on normal Rubrics

Paper Name: Major Project			Paper Code: IT 892									Session: 2014 - 2015
Name:	Tom Haykins		Roll No.:	201402009								
	#	Method/Element	Score (1–4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	4	4									
		Study, Investigation & Requirement Analysis	3	3	3		3						
		Planning & Designing, Creative Ability	3										
		Developing Solution/System	4			4							
		Application of latest Technology /Concept	4	4				4					
		Testing & Debugging	4		4	4		4					
		Documentation & Report	3									3	3
		Leadership & Teamwork	2								2		2
		Regularity	2							2			
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2			2						2	2
		Depth of Understanding & Preparation	3	3									
		Body Language, Confidence & Communication Skill	3									3	
		Q/A, Interaction, Manners	3	3								3	
		Assessment by University Examiner	3	3		3	3	3	3			3	
	2.2.5	Faculty and Staff Satisfaction Survey	2	2								2	
	2.2.5	Employer Survey	1			1		1				1	1
		Weighted Score (WS)		3.14	3.50	2.80	3.00	3.00	3.00	2.00	2.00	2.43	2.00
		%PO attained		78.57	87.50	70.00	75.00	75.00	75.00	50.00	50.00	60.71	50.00

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Figure 18. Scoring based assessment of Mr. Tom Haykins for IT891 based on normal Rubrics

Paper Name: Major Project			Paper Code: IT 891										Session: 2014 - 2015
Name:	Tom Haykins		Roll No.:	201402009									
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11	PO 12
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	3	3										
		Study, Investigation & Requirement Analysis	3	3	3		3							
		Planning & Designing, Creative Ability	2			2								
		Developing Solution/System	2			2								
		Application of latest Technology /Concept	2	2				2						
		Testing & Debugging	3		3	3		3						
		Documentation & Report	2									2	2	
		Leadership & Teamwork	4								4		4	
		Regularity	2							2				
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	3			3						3	3	
		Depth of Understanding & Preparation	3	3										
		Body Language, Confidence & Communication Skill	3									3		
		Q/A, Interaction, Manners	3	3								3		
		Assessment by University Examiner	3	3		3	3	3	3			3		
	2.2.5	Faculty and Staff Satisfaction Survey	2	2								2		
	2.2.5	Employer Survey	2			2		2				2	2	
		Weighted Score (WS)		2.71	3.00	2.50	3.00	2.50	3.00	2.00	4.00	2.57	2.75	1.00
		%PO attained		67.86	75.00	62.50	75.00	62.50	75.00	50.00	100.00	64.29	68.75	0.00

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Figure 19. Scoring based assessment of Mr. Russel Hilfiger for IT892 based on normal Rubrics

Paper Name: Major Project			Paper Code: IT 892									Session: 2014 - 2015
Name:	Russel Hilfiger		Roll No.:	201402011								
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	3	3									
		Study, Investigation & Requirement Analysis	3	3	3		3						
		Planning & Designing, Creative Ability	2										
		Developing Solution/System	2			2							
		Application of latest Technology /Concept	2	2				2					
		Testing & Debugging	2		2	2		2					
		Documentation & Report	2									2	2
		Leadership & Teamwork	4								4		4
		Regularity	2							2			
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	2			2						2	2
		Depth of Understanding & Preparation	3	3									
		Body Language, Confidence & Communication Skill	2									2	
		Q/A, Interaction, Manners	3	3								3	
		Assessment by University Examiner	2	2		2	2	2	2			2	
	2.2.5	Faculty and Staff Satisfaction Survey	2	2								2	
	2.2.5	Employer Survey	2			2		2				2	2
		Weighted Score (WS)		2.57	2.50	2.00	2.50	2.00	2.00	2.00	4.00	2.14	2.50
		%PO attained		64.29	62.50	50.00	62.50	50.00	50.00	50.00	100.00	53.57	62.50

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Figure 20. Scoring based assessment of Mr. Russel Hilfiger for IT891 based on normal Rubrics

Paper Name: Major Project			Paper Code: IT 891											Session: 2014 - 2015
Name:		Russel Hilfiger		Roll No.:		201402011								
	#	Method/Element	Score (1 – 4)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 11	PO 12
Major Project (Continuous Assessment)	1.1.12	Research & Literature Survey	2	2										
		Study, Investigation & Requirement Analysis	3	3	3		3							
		Planning & Designing, Creative Ability	2			2								
		Developing Solution/System	2			2								
		Application of latest Technology /Concept	2	2				2						
		Testing & Debugging	3		3	3		3						
		Documentation & Report	2									2	2	
		Leadership & Teamwork	4								4		4	
		Regularity	2							2				
Terminal Test/ Project Presentation	1.2.3	Quality of Technical Content, Planning & Adherence to Context, Demo of Prototype	3			3						3	3	
		Depth of Understanding & Preparation	3	3										
		Body Language, Confidence & Communication Skill	3									3		
		Q/A, Interaction, Manners	3	3								3		
		Assessment by University Examiner	3	3		3	3	3	3			3		
	2.2.5	Faculty and Staff Satisfaction Survey	2	2								2		
	2.2.5	Employer Survey	2			2		2				2	2	
		Weighted Score (WS)		2.57	3.00	2.50	3.00	2.50	3.00	2.00	4.00	2.57	2.75	1.00
		%PO attained		64.29	75.00	62.50	75.00	62.50	75.00	50.00	100.00	64.29	68.75	0.00

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Table 12. Standard deviations of % POs attained for IT 891 and IT 892 using Open Right Sigmoidal and Gaussian Fuzzifiers

Open Right Sigmoidal				Gaussian			
Tom Haykins		Russel Hilfiger		Tom Haykins		Russel Hilfiger	
IT 891	IT 892	IT 891	IT 892	IT 891	IT 892	IT 891	IT 892
7.9744	**11.9214**	**8.5058**	**6.0468**	15.5136	13.1509	15.6803	9.3051

Table 13. Standard deviations of % POs attained for IT 891 and IT 892 using Triangular Fuzzifier and Normal Rubrics

Triangular				Normal			
Tom Haykins		Russel Hilfiger		Tom Haykins		Russel Hilfiger	
IT 891	IT 892	IT 891	IT 892	IT 891	IT 892	IT 891	IT 892
19.8437	19.2015	14.4599	8.23145	24.4789	13.5866	24.4421	15.1863

The performance of the proposed fuzzy scoring mechanisms has been evaluated by computing the standard deviations of the %*POs* attained using the three different fuzzifiers and the conventional normal rubrics based assessment system. Tables 12 and 13 show the standard deviation of the %*POs* attained using the proposed fuzzifiers and normal rubrics. The best results have been marked in **boldfaced** for easy reckoning. It is observed that the standard deviation values obtained with the Open Sigmoidal fuzzifier are lower compared to all the other methods indicating a lower spread in the %*PO* values attained. Moreover, it is also observed from Figures 9 to 12 that the Triangular fuzzifier exhibits discontinuous values for %*PO* attained, as marked by **NULL** in the respective fields. Thus, it is evident from Tables 12 and 13 that the Open Right Sigmoidal fuzzifier shows the best performance as compared to the other fuzzifiers and the normal rubrics based assessment strategies.
The suitability of the proposed fuzzy model is quite justified by the objective nature of the values of %*PO* attained for the different students with different fuzzifiers under consideration. All the fuzzifiers reveal quantitative assessment of the rubrics based assessment scores using the proposed fuzzification scheme, which otherwise, remained a challenging proposition using the conventional normal rubrics based subjective assessment. Thus, it can be concluded that the proposed soft computing based assessment of rubrics stands out useful for objective evaluation of the performances of the students in an academic framework.
Hence, it is quite evident that the proposed fuzzy scoring mechanism is efficient enough to be applied as a universal scoring strategy for deriving a quantitative assessment of the performance of the students for different courses in line with the requirements of the outcome based technical education. Thus, the reflection of the outcomes of different courses effectively assimilated in the students under an accredited technical education program is greatly achieved by this proposed soft computing based quantitative assessment of rubrics. Moreover, it is also worth mentioning that the proposed model, having a universal objective assessment mechanism, can also be applied to any other course under any any other discipline of any educational institution.

9.1.5. Sensitivity Analysis of Fuzzy Models

The performance of a fuzzy model depends on the validity/suitability of the membership function characterizing the model and the appropriateness of the inputs for generating a desired outcome [49]. Given a fuzzy membership function, the sensitivity of the fuzzy model depends on the range of allowable deviations in the inputs which will not affect the outcome to an appreciable extent. However, the sensitivity of a fuzzy model is influenced by a non-linear behavior in that there is always an asymmetry in the outcome when the inputs are perturbed. Thus, an input perturbed to a certain direction (+ve direction) may increase the outcome, but the reverse is not always true, i.e., a perturbation in the opposite direction (-ve dierction) may not change the outcome in the same direction as well. This

non-linear behavior arises due to the participation of several inputs in a fuzzy model, which may cancel the desired changes. However, it follows from [49] that the outcome of a single input fuzzy model is insensitive to any change in the input to the model.
Since the considered fuzzy model as shown in Figure 4 is a single input fuzzy model with individual POs being serving as inputs to individual fuzzifiers, it can be inferred that the individual fuzzy models are insensitive to any change in the respective POs.

10. Discussions and Conclusion

A soft computing approach for deriving a quantitative assessment of the scoring grade of students based on rubrics based assessment is proposed in this chapter. Three different fuzzifiers are used to reason out the qualitative rubrics leading to a quantitative assessment of the performance of the students in a teaching-learning framework. Simulation results reveal the effectiveness of the proposed fuzzification scheme over the conventional normal rubrics based assessment mechanism. It is also found that the Open Right Sigmoidal fuzzifier outperforms other fuzzifiers under consideration as regards to the spread of the $\%PO$ values attained. Thus, it can be summarized that the proposed approach is versatile enough to be adopted for every courses following outcome based education.
However, the proposed approach resorts to a homogeneous fuzzifier scheme with all the individual fuzzifiers being of the same type. Methods however, remain to be investigated to apply a heterogeneous fuzzifier scheme involving different fuzzifiers for the individual POs. Moreover, methods also remain to be explored to apply evolutionary fuzzy systems to determine the optimized fuzzy memberships/weights for the different fuzzy levels of the fuzzifiers. The authors are currently engaged in these directions.

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