AN INTERVAL-VALUED FUZZY SET APPROACH FOR EVALUATING STUDENTS' ANSWER SCRIPTS IN ENGINEERING MATHEMATICS 3: A CASE STUDY AT KOLEJ KEMAHIRAN TINGGI MARA BALIK PULAU

by

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LIST OF ABBREVIATIONS

KKTM	Kolej Kemahiran Tinggi MARA
MARA	Majlis Amanah Rakyat
FEM	Fuzzy Evaluation Method
GFEM	Generalized Fuzzy Evaluation Method
AHP	Analytic Hierarchy Process
FGS	Fuzzy Grading System
PARES	Platform for Adaptive and Reliable Evalution of Students
WWW	World Wide Web
SFS	Standard Fuzzy Sets
IVFEM	Interval-Valued Fuzzy Evaluation Method
iCGPA	Integrated Cumulative Grade Point Average

LIST OF SYMBOLS

$\in$	Belongs to
$\subset$	Subset
$\mu_A(x)$	The membership function
max	Maximum
S(Q,M)	Fuzzy similarity between fuzzy set *Q* and *M*
$\sum$	Summation of the equation
Qi	Question with value *i*
T(Qi)	Marks allocated for each question with value *i*
P(gi)	Mid-grade points
TS	Total score
$F(x_i)$	Maximum degree of satisfaction
CTS	Core of total score
NS	New intermediate score
D(Qj)	Full percentage marks allocated for each question with value *i*
$[a_{i1}, a_{i2}]$	The set $\{x_i : 0 \le a_{i1} \le a_{i2} \le 1 \text{ and } x, a_{i1}, a_{i2} \text{ are real number}\}$
$[b_{i1}, b_{i2}]$	The set $\{x_i : 0 \le b_{i1} \le b_{i2} \le 1 \text{ and } x, b_{i1}, b_{i2} \text{ are real number}\}$
$H(\overline{A}, \overline{B})$	Degree of similarity
M_i	Total mark of question with value *i*
N_i	Total mark by percentage of question with value *i*
$\tilde{Q}_i$	Inter-valued fuzzy mark
$\tilde{g}_i$	Fuzzy letter grade
λ	Index of optimism
$K(\tilde{g}_i)$	Grade point
$<$	Less than
$\le$	Less than or equal to

Pendekatan Selang Bernilai Set Kabur untuk Menilai Skrip Jawapan Pelajar dalam Matematik Kejuruteraan 3: Kajian Kes Di Kolej Kemahiran Tinggi Mara Balik Pulau

ABSTRAK

Secara amnya, institusi pendidikan perlu menyediakan laporan penilaian pelajar berdasarkan ujian atau peperiksaan dan kemungkinan tidak dapat dielakkan berlakunya kesilapan kecil. Maka dalam disertasi ini, satu kaedah yang sedia ada telah digunakan sebagai kaedah alternatif untuk menilai skrip jawapan pelajar iaitu kaedah penilaian selang bernilai set kabur berdasarkan helaian selang bernilai bagi gred kabur. Markah bagi setiap soalan telah diberikan berdasarkan jawapan pada skrip jawapan pelajar dan ditentukan melalui selang bernilai set kabur di antara nilai kosong dan satu. Tahap kesamaan di antara nilai selang markah kabur dan nilai asas selang set kabur akan ditentukan berdasarkan pengiraan fungsi kesamaan. Indeks keyakinan, λ akan ditentukan oleh penilai untuk menunjukkan tahap keyakinan penilai. Seterusnya sistem penggredan berdasarkan kaedah kabur ini akan dibandingkan dengan kaedah penilaian klasik yang sedia ada dimana untuk kaedah klasik, markah satu diberikan jika betul dan markah sifar jika salah. Keputusan penilaian hasil perbandingan di antara kedua-dua kaedah telah menunjukkan 70 peratus daripada 20 orang pelajar telah meningkat markah penilaian. Selain itu, 3 orang pelajar telah mengalami peningkatan gred manakala 5 orang pelajar mengalami penurunan gred apabila dinilai dengan menggunakan kaaedah penilaian selang bernilai bagi set kabur. Perbandingan penilaian ini juga menunjukkan bahawa julat di antara markah tertinggi dan markah terendah bagi kaedah klasik ialah 42 manakala bagi kaedah penilaian selang bernilai bagi set kabur ialah 13. Oleh itu, kajian ini telah membantu para pendidik (pemeriksa) untuk menggredkan markah penilaian yang berbeza dalam menghasilkan markah tunggal atau gred kepada pelajar. Pada masa yang sama, kajian ini dapat membantu mereka mengetahui tahap pencapaian pelajar dalam kursus yang dinilai. Kajian ini juga menunjukkan kebaikan dan kejayaan dalam mengaplikasikan teori set kabur terhadap sistem penggredan pelajar. Dengan ini, kaedah penilaian selang bernilai bagi set kabur ini boleh menilai skrip jawapan pelajar dengan lebih fleksibel dan lebih bijak.

An Interval-Valued Fuzzy Set Approach for Evaluating Students' Answer Scripts in Engineering Mathematics 3: A Case Study at Kolej Kemahiran Tinggi Mara Balik Pulau

ABSTRACT

Generally, education institutions must provide students' evaluation reports regarding their test or examination as sufficient as possible and with the unavoidable error as small as possible. Therefore in this dissertation, the existing method had been used as an alternative method for evaluating students' answer scripts that is interval-valued fuzzy set based on interval-valued fuzzy grade sheets. The marks for each question have been awarded to the answer in the students' answer scripts are represented by interval-valued fuzzy sets by an interval between zero and one. The degree of similarity between an interval-valued fuzzy mark and a standard interval-valued fuzzy set will be calculated by similarity function. An index of optimism, λ will be determined by the evaluator. It is used to indicate the degree of optimism of the evaluator. Then, the grading system based on fuzzy method will be compared with classical evaluation method where the score is given one if it is true and zero marks when it is false. The result of the evaluation between two methods shows that 70 percent of the 20 students increase the marks. Besides that, 3 students increase their grade meanwhile 5 students decrease their grading when using interval-valued fuzzy set method. It has also shown that the range between the highest and the lowest marks for classical evaluation method is 42 and for interval-valued fuzzy set method are 13. This dissertation help examiners graded different assessment score in generating single score or grade and also help them knowing the student's achievement level in the assessed course. This dissertation also showed a good and successful fuzzy set theory application on student grading system. An interval-valued fuzzy set method can evaluate students' answer scripts in a more flexible and more intelligent manner.

CHAPTER 1

INTRODUCTION

1.1 Overview

Student evaluation is a very complex process that should take many factors. Recognizing the limits of various grading practices and balancing them with common sense and good judgment is an important part of the work of professional educators. The formal testing and evaluation systems in education and their grading practices are a very recent educational phenomenon. In the 1870s, the first public examination system was instituted when the upper ranks of the mushrooming British civil service could no longer be filled through nomination. In 1911, teachers had testing the reliability of the marks entered on the cards showed that the same material could be assigned widely different marks depending on the markers. In the years from 1911 to 1960, school systems experimented with various letter and number reporting conventions (Moll, 1998).

Percentage grading was the most popular system during the latter half of the 19th and the early part of the 20th century. Most of the educational institutions switched from numerical to letter grades during the 1930s and 1940s, which represented groups of percentages. In the 1960s, some of the institutions move to simple pass or fail options and written evaluations. Recently surveys have shown that letter grades (A, B, C, D, F) remain the most common grading practice in educational systems so far (Moll, 1998).

Student academic performance evaluation involves several components, each based on number of imprecise judgments arising due to human (teacher or tutor) interpretation. Both arithmetical and statistical methods have been used for aggregating information from these assessment components in educational domain. These commonly used methods have some limitations. For example, in a scenario two student's score**s** are 50, 60, 70 and 70, 60, 50 in three questions, respectively. The average mark obtained by each is 60 without any indication of their intelligence level.

The main aim of educational institutions is to provide student with the evaluation reports regarding their examination as best as possible with minimum errors. Some factors other than academic have been reported to creates barrier to students attaining and maintaining their high performance. Grouping or clustering of students using cognitive as well as affective factors and then defining the performance measure may be a realistic approach.

1.2 Research Background

An application based on the fuzzy sets theory is synonymous with the fields of engineering and computer science. In order to explain the concepts of fuzzy sets, the basic idea in classical set theory must be understood. In mathematics, the concept of classical set is very simple. A set is a collection of well-defined objects. These objects cover almost anything that can either belong or do not belong to the set.

The classical set *A* in the universe *U*, $A \subset U$ is normally characterised by the function $\mu_A(x)$, which take the value 1 or 0, indicating whether or not $x \in U$ is a member of *A*:

$$\mu_A(x) = \begin{cases} 1 & for \quad x \in A, \\ 0 & for \quad x \in A. \end{cases} \tag{1.1}$$

Hence, $\mu_A(x) \in \{0,1\}$. The function $\mu_A(x)$ as equation (1.1) takes only the value 1 or 0. Assume that the function $\mu_A(x)$ may take values in the interval [0, 1], the concept of membership is not any more crisp, but become fuzzy in the sense of representing partial belonging or degree of membership (G.Bojadziev, 1999). A fuzzy set *R* is defined by

$$R = \{(x, \mu_R(x)) / \, x \in A, \mu_R(x) \in [0,1]\}, \tag{1.2}$$

where $\mu_R(x)$ is a function called membership function; $\mu_R(x)$ specifies the grade or degree to which any element in *A* belongs to the fuzzy set *R*.

Ragin (2000) had a very simple explanation about fuzzy sets. He iterated that the basic idea behind fuzzy sets is to permit the scaling of membership scores and this allows partial or fuzzy membership. A membership score of 1 indicates full membership in a set; a score close to 1 (e.g., 0.8 or 0.9) indicates strong but partial membership in a set; scores less than 0.5 but greater than 0 (e.g., 0.2 and 0.3) indicate that objects are more "out" than "in" a set, but still weak members of the set; a score of 0 indicates full non membership in the set. Thus, fuzzy sets combine qualitative and quantitative assessment.

Fuzzy evaluation method (FEM) for applying fuzzy sets in students' answer script evaluation has been proposed by Biswas (1995). The fuzzy marks awarded to student's answer scripts can be represented by fuzzy sets. In a fuzzy set, the grade of membership of an element μ_i in the universe of discourse *U* belonging to a fuzzy set is represented by a real value between zero and one.

1.3 Problem Statement

Biswas (1995) has proposed a generalized fuzzy evaluation method for students' answer scripts evaluation. He also pointed out that the paradigm of the fuzzy evaluation methods is a confluence of the fuzzy set theory. This method is potentially finer than the non-fuzzy traditional methods of evaluation. However, Biswas's method has two drawbacks (Chen and Lee, 1999). They stated that it will take a large amount of time for dealing with the matching operations of the matching function. Besides that, two different fuzzy marks may be translated into the same awarded letter grade. These drawbacks are an unfair to the students' evaluation.

Besides that, Chen and Wang (2009) have presented two new methods for evaluating students' answer scripts based on interval-valued fuzzy grade sheets that can be used to solve problem in Biswas's method. Therefore, by referring to the papers, this dissertation will employ Chen and Wang's method for evaluating students' answer scripts at Kolej Kemahiran Tinggi MARA (KKTM) Balik Pulau. The Chen and Wang's method is based on interval-valued fuzzy sets.

Students' evaluation for grading in a course at KKTM Balik Pulau has different type of assessment regarding to the needs of the course based on each programme learning outcomes. Engineering Mathematics 3 (HUM 3132) is one of the courses that have been offered to the students to complete their studies. They have to complete five types of assessment such as quizzes, theory assignment, numerical theory test 1, numerical theory test 2 and final theory. Evaluation for each type of assessment is based on the marking scheme that has been provided. The mark awarded to the each questions for the students' answer scripts is 0 or 1 for every step of answer. Finally, the marks for each question will be total for their grading.

Some of the question that been answered by the students' will be awarded 0 mark even though the students gave actual method or they careless in doing the calculation. In my opinion, it is fairness to award the students' mark in between 0 to 1 because the students still have the knowledge of answering the question. Besides that the marks and grades between the highest and lowest total marks will be small in range. Therefore, by evaluate students' answer scripts with this approach it will give more flexible and more fairness to the marks and grading.

1.4 Objectives

The objectives of this dissertation are as follow:

i. To apply the Chen and Wang's method for evaluating students' answer scripts at Kolej Kemahiran Tinggi MARA (KKTM) Balik Pulau.

ii. To compare the results of using Chen and Wang's method with the classical evaluation method.

1.5 Scope of the Study

The scope of this dissertation is to use Chen and Wang's method to evaluate students' answer scripts based on interval-valued fuzzy grade sheets. This dissertation will be focusing on a course of Engineering Mathematics 3 (HUM 3132) at Kolej Kemahiran Tinggi MARA (KKTM) Balik Pulau. This course is a compulsory course for semester 3 students. This course is only assessed for students in KKTM Balik Pulau although throughout Malaysia there are 11 KKTM campuses due to different codes and syllabus.

By using cluster sampling technique, evaluation and data collection are focused on students pursuing Diploma of Technology Engineering Stamping Die of 20 students that are in this programme. The evaluation only involves 20 students is due to this students that are only registered for Engineering Mathematics 3 course in that semester. Some questions of the final examination from Engineering Mathematics 3 (HUM 3132) will be evaluated by classical method and interval-valued fuzzy method. The marks awarded to the answers in the students' answer scripts will be represented by classical mark grade sheet and interval-valued grade sheet.

1.6 Dissertation Outline

This dissertation is divided into five chapters. Chapter 1 mentioned about the history and the main aim of student evaluation in educational systems. It is also explain the definition of fuzzy sets theory and the methods that are applying fuzzy sets in

students' answer scripts evaluation which are related with the dissertation. Finally, this chapter stated the objectives and the scope of the study in this dissertation.

In Chapter 2, it provides some previous studies which relevant or related to this dissertation. The methodologies used by previous researchers are discussed. The methods that are related with evaluating on the students' answer scripts and students' academic performance have been reviewed. Biswas's, Chen and Lee's, Law's and Chen and Wang's approach are elaborate from the previous research.

Chapter 3 presents the method used of this study. Chen and Wang's method are more flexible and more intelligent in evaluating students' answer scripts compared to other approaches from the precious researchers. The classical evaluation method and the interval-valued fuzzy evaluation method are involved and finally the calculation of total marks from the evaluation of both methods.

In Chapter 4, it provides the results of the calculation on total marks for classical evaluation method and interval-valued fuzzy evaluation method. It also discussed the comparison of both methods. The result and some discussions are explained and presented graphically in this chapter.

As for the conclusion in Chapter 5, the results obtained in this dissertation are concluded and some possible extensions of the present work for the future study are discussed.

1.7 Summary

In this chapter, we have mentioned the history and how's the student evaluation have started from 1870s until the process of student evaluation process are very complex nowadays. The concept of classical set and fuzzy sets theory has been explained easily. Finally, Chen and Wang's method have been describe and employ for evaluating students' answer scripts at Kolej Kemahiran Tinggi MARA (KKTM) Balik Pulau to achieve the objectives of dissertation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides some of the previous researchers' works and review of methods related to evaluating on the students' answer scripts and the students' academic performance evaluation for the enhancement to the better of understanding. The existing research of evaluating the students' answer scripts has been elaborated. Apart of this, selected methods used for evaluating students' answer scripts have been described in detail.

2.2 General Theory of Fuzzy Set

Fuzzy sets were introduced by Lotfi Zadeh (1965) as an extension of classical notation set. Classical set theory allows the membership of the elements in the set in binary terms. Fuzzy set theory permits membership function valued in the interval 0 and 1. Words like young, tall, good or high are fuzzy. There is no single quantitative value which defines the term young. For some people, age 25 is young, and for others, age 35 is young. The concept young has no clean boundary. Age 35 has some possibility of being young and usually depends on the context in which it is being considered.

Fuzzy set theory is an extension of classical set theory where elements have degree of membership (Zadeh, 1965). In real world, there exist much fuzzy knowledge

which are vague and uncertain inexact. Human thinking and reasoning for analyzing, logic and interpretation frequently involved fuzzy information. Human can give satisfactory answers, which are probably true. Our systems are unable to answer many questions because the systems are designed based upon classical set theory that is unreliable and incomplete information. The fuzzy system should be able to cope and provide the solution.

A classical set is defined by crisp boundaries. There is no uncertainty about the location of the set boundaries. Usually an ordinary set which is a classical or crisp set is called a collection of objects. These objects have some properties distinguishing them from other objects which do not possess these properties. An object in a set is called an element or member of that set. Sets are defined by a simple statement, describing whether a particular element having a certain property belongs to that particular set. For $A = \{a_1, a_2, a_3, ..., a_n\}$, if the element $a_i \ (i = 1,2,3,.....,n)$ of a set *A* are subset of universal set *X*, then set *A* can be represented for all elements $x \in X$ by its characteristics function $\mu_A(x)$ = 1, if $x \in X$ otherwise 0.

A fuzzy set is defined by its ambiguous boundaries. There exists uncertainty about the location of the set boundaries. Elements have varying degree of membership. A logic based on two truth values, true and false is sometimes insufficient when describing human reasoning. Fuzzy logic is derived from fuzzy set theory which uses the whole interval between 0 (false) and 1 (true) to describe human reasoning. Fuzzy set is any set that allows its members to have different degree of membership, called membership function, having interval [0,1]. Thus membership function $\mu_A(x)$ is

associated with a fuzzy set $\tilde{A}$ such that function maps every element of universe of discourse *X* to the interval [0,1]. The mapping is written as: $\mu_A(x): X \rightarrow [0,1]$.

If *X* is an universe of discourse and *x* is a particular element of *X*, then a fuzzy set *A* defined on *X* and can be written as a collection of ordered pairs $A = \{(x, \mu_{\tilde{A}}(x)), x \in X\}$. For example, let $X = \{g_1, g_2, g_3, g_4, g_5\}$ be the reference set of students and let $\tilde{A}$ be the fuzzy set of "smart" students, where "smart" is fuzzy term, therefore $\tilde{A} = \{(g_1, 0.4)(g_2, 0.5)(g_3, 1)(g_4, 0.9)(g_5, 0.8)\}$. $\tilde{A}$ indicates that the smartness of g_1 is 0.4, g_2 is 0.5, g_3 is 1, g_4 is 0.9 and g_5 is 0.8. The membership function fully defines the fuzzy set. A membership function provides a measure of the degree of similarity on an element to a fuzzy set. Membership functions can either be chosen by the user arbitrarily, based on the user's experience where membership function chosen by two users could be different depending upon their experiences.

The concept of fuzzy logic which derived from fuzzy set theory is based on near the human thinking and natural activities. This theory implies human psychology on how a person makes a decision faster. Fuzzy set provide an ultimate mechanism of communication between human and computing environment. Fuzzy logic has applications in various fields (Poonam Gupta, 2017). In this paper, applications of fuzzy logic such as transportation, fuzzy logic washing machine, room air cooler and application in medical science had been discussed. This various applications are very difficult to solve with traditional analytical techniques. In this situation, fuzzy logic theory had proved itself very beneficial and fruitful. Fuzzy logic has been provided to be an excellent choice for many control system application.

2.3 Existing Fuzzy Research of Student Evaluation

Teachers or educators in educational institutions must provide students with assessment reports regarding with the students examination as sufficient as possible and reducing error of evaluation as small as possible is one of the main goal of educational institutions (Biswas, 1995). Zadeh has proposed the fuzzy sets theory in 1965. Some research on the use of fuzzy set theory (Zadeh, 1965) in education has been studied in recent years including evaluating student answer scripts. Some application that based on fuzzy set theory has been presented for students assessment is to deal with the fuzziness in the process of students' evaluation.

A method for fuzzy assessment of learning performance of junior high school students (Chang & Sun, 1993) has been presented to explore the applicability of K-means which is and Fuzzy C-Means clustering algorithms. The student's academic performance has been analyzed to determine new students to the maximum homogeneous capacity group and the impact on those provisions. Dynamic Fuzzy Expert System model has been used to presents a fuzzy set and regression analysis. This model is able to deal with the accuracy and loss of data that is usually inherited in evaluating student academic performance and by using C-Means clustering algorithm method; it is automatically converts crisp sets into fuzzy sets. The analysis of performance by comparison shows that the student group formed by Fuzzy C-Means clustering algorithm are performed better than groups formed by K-Means and Bayesian classifications.

A Fuzzy Evaluation Method (FEM) and Generalized Fuzzy Evaluation Method (GFEM) have been presented by Biswas for applying fuzzy sets in students' answer scripts evaluation (Biswas, 1995). In this paper, two systems which are grading method and traditional marking method are used to evaluate the students' answer scripts. After that he has suggested a better method of evaluation by using a computer based on fuzzy approach where a vector valued marking is used called FEM. Finally generalized method from FEM called GFEM in which a matrix-valued marking is adopted. This paper shows a good and successful application of fuzzy set theory initiated by Zadeh in 1965. However, Chen and Lee mentioned that this method by Biswas has two drawbacks when they presented their methods in evaluating students' answer scripts by using the fuzzy sets theory (Chen & Lee, 1999). The drawbacks are it takes to much time to dealing with matching operations and matching functions and secondly it sometimes can awarded same letter grades if two different fuzzy marks given. These drawbacks will give an unfair result to the students in evaluating students' answer scripts.

Analytic Hierarchy Process (AHP) method (Frair, 1995) is used evaluates the contributions of engineering student team member for student peer assessments. The assessments are involving the contribution and effort of the individual in a team in doing an assignment to making a final determination. This evaluation can provide candid student peer input by using this AHP method and it can be characterized as a technique of multi-criteria decision in which qualitative factors are of prime of importance. In this paper, a hierarchical representative is used to develop a model of the problem. The main objective is to fulfil at the top of the hierarchy and the progressive decomposition of the problem will be representing at the lower level. The experienced