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Effect of using 4mat method on academic achievement and attitudes toward engineering economy for undergraduate students

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The study examined effect of 4MAT method on academic achievement and attitudes toward engineering economy for undergraduate students. Comparison between 4MAT and traditional method in teaching selected units from engineering economy course had been conducted. The sample of this study included 80 under graduate students in two separate groups. One of the groups was considered as an experimental group in which 4MAT method was applied; and the other was considered as a control group in which the traditional teaching has been delivered. Data was obtained from two scales, engineering economy attitude scale and knowledge test on foundations of engineering economy and present worth analysis units. It was concluded that students who are guided through 4MAT are exposed to a variety of learning experiences and increased chances for academic achievement and attitudes toward engineering economy. In addition, 4MAT method provides a rational foundation for faculty members, who might have hesitated to bring creativity into the classroom, and to develop activities beyond the traditional lecture. Also, the application of 4MAT in engineering classroom leads to renewed interest for the educational process and a greater commitment to teaching and learning

Key words: 4MAT, learning style, academic achievement, attitudes, engineering economy.

INTRODUCTION

The individual's preference for how to learn is the manifestation of learning style (Harb et al., 1991). One of the most famous definitions of learning style is the individually approximation for gathering and treating information or knowledge, creating ideas, and taking a decision (Orhun, 2007). Other definitions have been provided by educational researchers; for example, it is the favorite of the person in using his ability of recognizing and processing the information (Nicoll and

Joan, 2009).

It is well known that success can be attained with the effective learning which is established by the prepared education programs (Tatar and Dekici, 2009). When students were taught through their preferred learning style they show substantial improvement in their attitudes towards subject, better recognition for perceptive diversity, significant enhancement of academic achievement, and more self-commitment for homework

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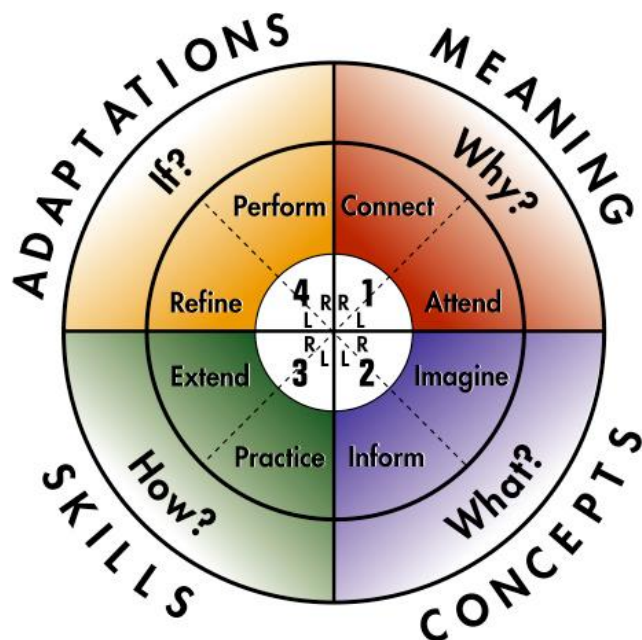


Figure 1. 4MAT system (www.4mationweb.com, 2003).

completion (Given, 1996; Hein and Budny, 1999). 4MAT system has been developed by McCarthy as one of the well-known systems of instructions that is applied in teaching. McCarthy's 4MAT system is based on Kolb's work (Kolb, 1984). The main purpose of such system was to employ a beneficial learning environment. 4MAT system is a process for conveying instructions in a way that involves, informs, and permits practice and creative use of material learned within each class. The system reflects the learning process as a journey by asking four simple questions; why?, what?, how?, and if?. Why question pursues a reason or motivation for learning; what question searches for knowledge and information; how question tries to find a way for applying the knowledge; and if question develops extensions for the learners to generate new experiences regarding the learned material (Guild and Garger, 1998).

The 4MAT system aids instructors to organize their teaching based on individual differences in the way people learn. 4MAT is an eight step cycle of instruction that capitalizes on individual learning styles and brain dominance processing preferences. 4MAT system is based on research from different fields of education, psychology, neurology and management (McCarthy, 1990). Figure 1 shows the eight quadrants of 4MAT system. The system considers the style that each student brings to the classroom, while serving each student develops by mastering the entire cycle of learning styles (McCarthy, 1997). The main concept of 4MAT system can be summarized as: the brain has two halves, right and left hemispheres and these two halves process information in different manners; in the split-brain patient,

there seem to be two different people up there, each with his/her preferred ways of processing information, each with a different mode of thinking; both hemisphere are equally important (Tatar and Dekici., 2009). The left brain is rational, verbal, serial and analytical. Analysis and planning are key strategies of left brain. On the other hand, the right brain is visual, inclusive, and general, able to perceive shapes and relations. Right brain processing seeks patterns and solves problems by looking at the whole image. Sensitivity, theories and opinions are key processing strategies of right brain (McCarthy, 1997). It has been indicated that both hemispheres with different learning functions of the brain must be engaged in the learning activities to acquire an efficient learning and a permanent memory (Tatar and Dekici, 2009).

Referring to McCarthy, 4MAT system has four learning styles to recognize and process the received information. Type one learners are principally interested in personal meaning. Type two learners are keen on the details as they result in conceptual understanding. Type three learners look for how things work and the practical side of the concept. Type four learners are interested in improvement and self-discovery (McCarthy, 1987). The 4MAT cycle contains eight activities cooperative each of the four types of learning using both right- and left-brain processing procedures in each quadrant (Tatar and Dekici, 2009). Most of the learners like to be taught in all four techniques while being strained to develop other learning abilities. According to Morris and McCarthy (1990), all learners will engage at different places in the learning cycle. This will permit them to learn from each other (Kaplan, 1998).

LITERATURE REVIEW

Recently, 4MAT has applications across different educational levels and disciplines such as medicine education (Spatz, 1991; Erwin et al., 1992), law studies (Kelly, 1990) and science (Bowers, 1987; Ursin, 1995; Jackson, 2001). For example, many teaching methods were applied to meet the learning style of the students in engineering economy. An experiential learning cycle and a novel business game were applied to allow the present value of an alternative to be calculated quickly (Mare, 1993). In order to transform a biostatistics course into a problem-based learning experience, Nowacki (2011) undertaken 4MAT model to learning process. The results showed that students felt more strongly, encouraged sharing and integrated concepts across the subject. Furthermore, recommendations regarding problem-based learning techniques were provided. Studies of the 4MAT model were also accompanied at different levels of education. The obtained results showed that applying of 4MAT model resulted in positive attitudes, enhancing of academic achievement and more long-life learning (Dikkartin, 2006; Ergin and Sari, 2012; Tatar and Dikici, 2009; Uyangor, 2012). The influence of learning

activities on academic attainment and attitude towards mathematics of high school students were investigated by Kemal and Huseyin (2014) who developed an approach matched with 4MAT system. The results showed an enhancement in the academic attainment and problem solving. Uyangor and Sevinc (2012) investigated the impacts of the 4MAT model on academic attainment and attitudes towards mathematics of seventh year grade students at public schools. The authors applied an experimental model on a control group with a pre-test and post-test. The results revealed more efficient of 4MAT method than the traditional method (Uyangor and Sevinc, 2012). The work of Aktas and Bilgin (2015) considered the effects of the 4MAT learning model on seventh Grade students' academic achievement and motivation on the 'Particulate Nature of Matter'. The results showed an effectiveness of 4MAT model rather than traditional method in terms of enhancement of achievement and motivation (Aktas and Bilgin, 2015).

Problem statement

The problems encountered in this study were the result of the following:

1. There is a lack of studies regarding the application of 4MAT in teaching engineering courses.
2. Comparing 4MAT method with traditional lecturing method in teaching engineering economy to undergraduate students hasn't been implemented before.
3. Effectiveness of 4MAT on the academic achievement and attitudes toward engineering economy for undergraduate students hasn't been investigated yet.

Significance of the study

The significance of this study has many sides: results obtained might assist in improving academic achievement of the students in engineering economy course by applying 4MAT method. This study may also affect positively the attitude of students toward engineering economy.

Furthermore, instructors will be able to apply 4MAT in engineering courses rather than engineering economy. Finally, the study aims to assist developers of engineering curriculum to benefit the 4MAT method when designing their curricula.

Study objectives

The main purpose of this study was to study the effectiveness of 4MAT method in teaching the foundations of engineering economy and present worth analysis units to under graduate students. The

researcher tries to answer the following questions:

Question 1: Would students taught via 4MAT perform better than students taught via traditional method on engineering economy?

Question 2: Does students' academic achievement in engineering economy for final year undergraduate students affected increase?

Question 3: Does students' attitude toward engineering economy affected positively?

Terminologies of study

4MAT system

The 4MAT system of instruction is a strategy dealing with individual differences. It is to develop or modify the procedures of teaching so that they specifically address individual differences of learners (Guild and Garger, 1998).

Academic achievement

Academic achievement is the learning outcomes that indicate to which extent a person has been able to achieve specific educational target (Huitt et al., 2009).

Attitude toward subject

The researchers used both definitions by Newcomb who defines attitude of students toward a subject as the organization of knowledge accompanied by negative or positive responses; Ajzen who stated that attitude toward a subject is an education preparedness to respond regularly and lovingly on a particular topic (Aql, 1985).

Variables of the Study

The study had 4MAT system as an independent variable while the two dependent variables were the academic achievement and attitude toward engineering economy.

Methodology and procedures

Population

The population of this study consisted of all under graduate students in college of engineering, Qassim University, Kingdom of Saudi Arabia.

Samples

The sample contained 80 students studying in final year of the

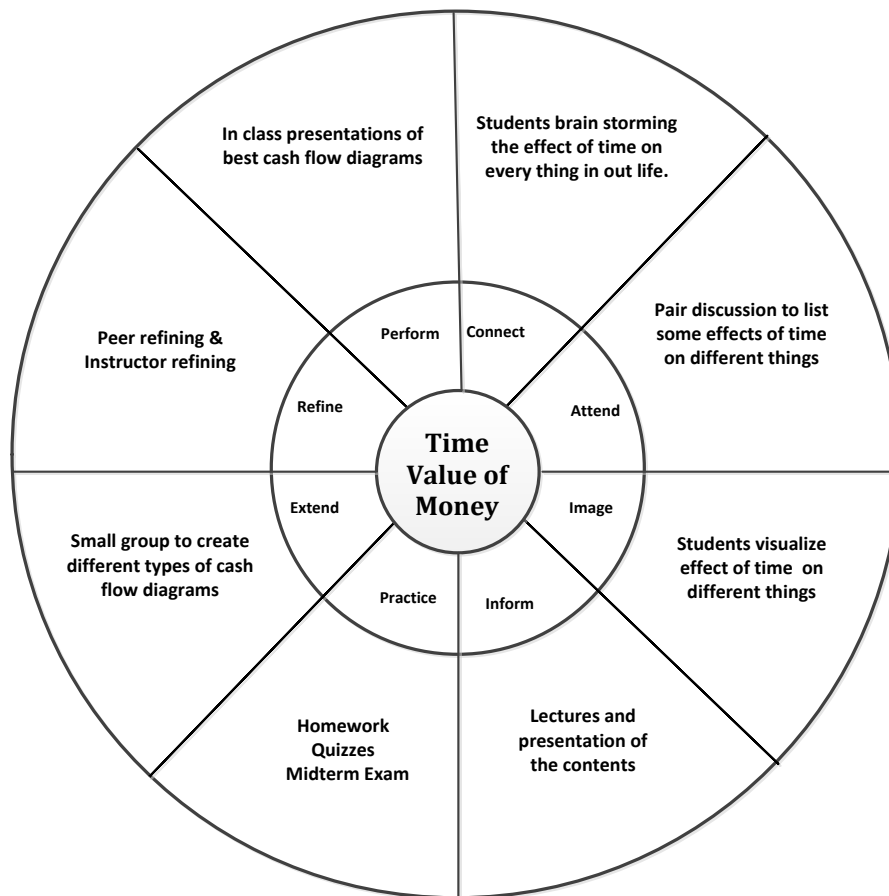


Figure 2. 4MAT wheel for the concept "Time Value of Money".

college and divided into two separate classes. One of the classes was considered as the experimental group ($n=45$) in which 4MAT method had been applied; and the other class was selected as a control group ($n=35$) in which the traditional teaching had been used, and this selection was performed randomly.

Data collection and Instruments

The data had been obtained from two scales, engineering economy attitude scale and foundations of engineering economy and present worth test.

Engineering economy attitude scale

In order to determine the attitudes of the students towards engineering economy, the researchers modified the scale that was developed by Fennema et al. (1976). The scale consists of four subscales: a confidence scale, a usefulness scale, a scale that measures engineering economy and a teacher perception scale. Each of these scales consists of items measuring a positive attitude and others measure a negative attitude.

Foundations of engineering economy and present worth test

A test consists of fifteen multiple choice questions covering the

contents of the selected units "Foundations of engineering economy and present worth" was prepared. The test topics were taken from the text book which has been approved by subject and program committees at the Faculty of Engineering, Qassim University, KSA. The test was peer reviewed by two staff member of the same profession. Thus, this form of test was applied to a student group to which the subject was lectured, and Cronbach Alpha reliability coefficient of the test was calculated and found to be 0.71. The high Cronbach's alpha coefficients indicate that the instrument is highly reliable.

Experimental application

The units of foundations of engineering economy and present worth were prepared, and converted to 4MAT model including the skills and activities required; also mind maps of the contents were constructed. Two 4MAT wheels of the main concepts were created by the researcher. The main concept of the unit "foundations of engineering economy" was "time value of money" while the main concept of unit "present worth analysis" was "alternatives". Both wheels are shown in Figures 2 and 3 while the mind maps, activities, and skills used in the experiments are shown in Tables 1 and 2. The applications of both 4MAT and traditional methods of instruction were conducted for a period of three weeks in first semester, "Fall" 2014/2015 academic year. The experimental methodology of the research is summarized in Table 3.

Both experimental and control groups have been taught by the

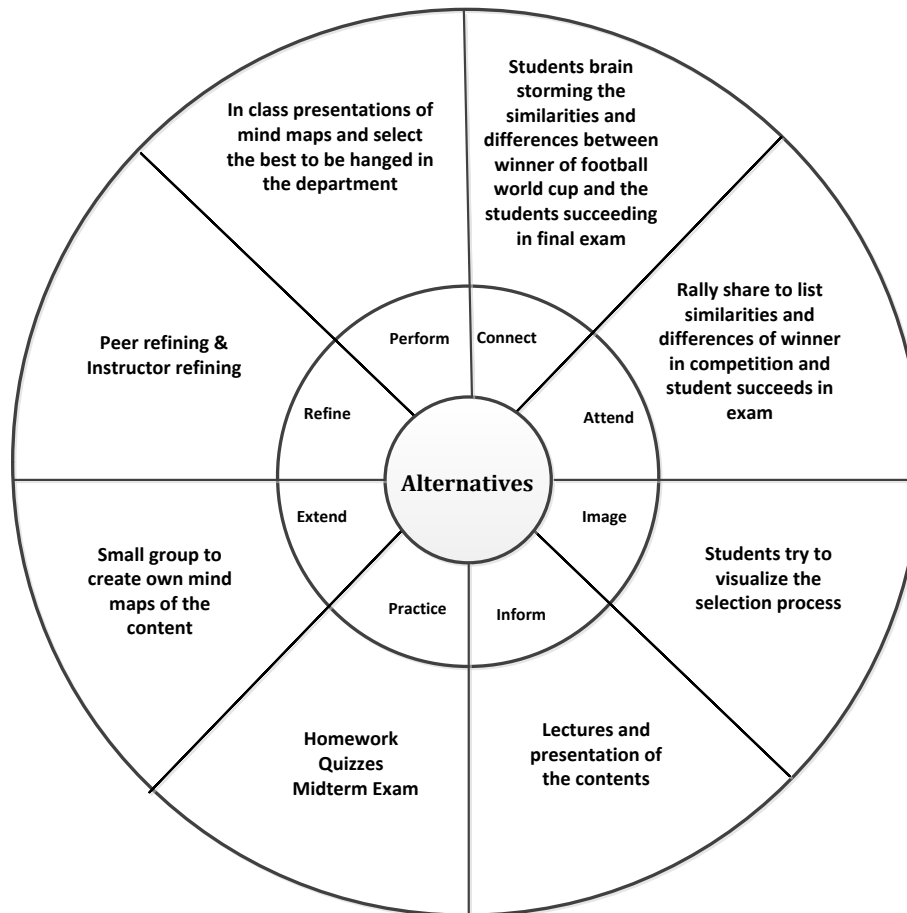


Figure 3. 4MAT wheel for the concept “Alternatives”.

corresponding author of this study. In the control group, traditional lecturing method of instruction was applied including problem solving and tutorials. In this phase of teaching 4MAT method was not applied. On the other hand, the experimental group was given a teaching based on 4MAT method. The teaching process of both the 4MAT and the traditional methods were completed in a total of 9 h over three studying weeks. In order to motivate students to work seriously, they were informed that the evaluation results affect the final grades. This was announced to the students before both the pre-test and post-test.

The textbook by Blank and Tarquin (2012) was used in the control group whereas 4MAT method was used in the experimental group by means of following the related subject content of the same book. The preparations were aided by works of Morris and McCarthy (1990), Terms (2005) and White (2005). Examples from steps used regarding the application of 4MAT on the experimental group are as follows:

Wheel (1): The main concept of this wheel is “time value of money”. Subject: Foundation of engineering economy.

Objective: Bringing up an experience by which the students can compare between simple interest and compound interest with respect to time.

Essential question: What would be the most important parameters and factors to be calculated or obtained to understand the effect of time on the value of money?

- Activities:

Quadrant (1) {Connect-Attend}: In this stage the instructor connected the experience of students with the concept through brain storming about effect of time on our life and things surrounding us. Attending the students to the concept was performed via pair discussion, and giving examples by the instructor about the effect of time on everything in our life with reasons (for example, Life, cars, buildings). The instructor gives intended questions to manage the discussion.

Quadrant (2) {Image-Inform}: Students worked in pairs and were asked to imagine the effect of time on specific objects and they tried to visualize the concept of time value of money. In order to bridge the gap between students experience and the contents of the unit to be taught, the instructor showed pictures and figures of a banks and graphs then a lecture was presented to inform the students about: definition of engineering economy, interest and interest rates (simple and compound), economical equivalence, symbols and terminology.

Quadrant (3) {Practice-Extend}: This quadrant includes the practice of the previous given information. Instructor gave exercises to be solved by each student in order to realize the difference between simple and compound interests. In order to extent the knowledge and practice of the students, the instructor asks them to construct different types of cash flows and interpret them in their own words.

Quadrant (4) {Refine - Perform}: During this quadrant, the refining is required so the instructor gives a real case problem to the students and they are asked to construct cash flow diagram of this case. The

Table 1. Concept, mind map, skills, and activities of unit “foundations of engineering economy”.

Learner outcomes	By the completion of this part, students will be able to: 1. Understand the basic concepts and roles of engineering economy. 2. Identify main engineering economy symbols and select compound interest factors.				
Content	Foundation of engineering economy				
Mind map					
Concept	Time value of money				
Essential question	What would be the most important parameters and factors to be calculated or obtained to understand the effect of time on the value of money?				
Bridge					
Quadrant Connect	<table> <thead> <tr> <th data-bbox="323 1444 383 1470">Skills</th><th data-bbox="581 1444 678 1470">Activities</th></tr> </thead> <tbody> <tr> <td data-bbox="323 1478 521 1602"> 1. Experiencing 2. Communication 3. Questioning 4. Listening </td><td data-bbox="581 1478 1471 1602"> Brain storming about effect of time on our life and things surrounding us Pair discussion and giving examples of effect of time with reasons (eg. Life - cars - buildings...etc. Asking intended questions - Discussion with students </td></tr> </tbody> </table>	Skills	Activities	1. Experiencing 2. Communication 3. Questioning 4. Listening	Brain storming about effect of time on our life and things surrounding us Pair discussion and giving examples of effect of time with reasons (eg. Life - cars - buildings...etc. Asking intended questions - Discussion with students
Skills	Activities				
1. Experiencing 2. Communication 3. Questioning 4. Listening	Brain storming about effect of time on our life and things surrounding us Pair discussion and giving examples of effect of time with reasons (eg. Life - cars - buildings...etc. Asking intended questions - Discussion with students				
Imagine Inform	<table> <tbody> <tr> <td data-bbox="323 1644 509 1734"> 1. Understanding 2. Imaging 3. Categorizing </td><td data-bbox="581 1644 1403 1734"> Students work in pairs to imagine the effect of time on objects Lecturing about: engineering economy- interest and interest rates (simple and compound) –equivalence – symbols and terminology </td></tr> </tbody> </table>	1. Understanding 2. Imaging 3. Categorizing	Students work in pairs to imagine the effect of time on objects Lecturing about: engineering economy- interest and interest rates (simple and compound) –equivalence – symbols and terminology		
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Practice Extend	<table> <tbody> <tr> <td data-bbox="323 1776 513 1860"> 1. Using formulas 2. Constructing diagrams </td><td data-bbox="581 1776 1471 1814"> Given exercises to solve and compare between simple and compound interest rates </td></tr> </tbody> </table>	1. Using formulas 2. Constructing diagrams	Given exercises to solve and compare between simple and compound interest rates		
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Table 2. Concept, mind map, skills and activities of unit “Present Worth Analysis”.

Learner outcomes	After completion of this part, students will be able to: 1. Solve problems related to present worth, analysis for engineering projects 2. Select from different engineering alternatives based on economic considerations	
Content	Present worth and annual worth analysis	
Mind map		
Concept Essential Question	Alternatives	
Bridge	Which criteria and guidelines would you follow to compare and select between alternatives on present and annual worth basis?	
Quadrant	Skills	Activities
Connect	1. Experiencing 2. Communication	1. Group discussions about the meaning of succeed in case of sport games and university results
Attend		2. Rally share to give differences in selection or winning 3. Discussion with students
Imagine	1. Defining 2. Selecting 3. Analyzing	Students will be asked to draw sketches of how can they imagine the selection process Lecturing about: present worth an annual worth analysis – capitalized costs – AW analysis – permanent investment
Inform		
Practice	1.Using formulas 2. Constructing diagrams 3. Comparing 4. Solving problems	1. Given exercises to solve and compare between alternatives on economic bases 2. Working in groups to compare between projects by applying study periods and LCM 3. Pairs will select from alternatives based on independent approach
Extend		
Refine	1. Developing 2. Sharing	1. Students will create complete mind map of the contents
Perform		2. Presentation will be held and best mind map will be chosen to be showed in the department

Table 3. Experimental methodology.

Instruction method	Group	Sample Size, (n)	Pre-test	Post-test
4MAT	Experimental	45	T ₁ , T ₂	T ₂
Traditional	Control	35	T ₁ , T ₂	T ₂

T₁: Engineering economy attitude scale; T₂: Present and annual worth knowledge test.

students work in small groups (4 to 6 students) to prepare in class presentation for the solution. Both peer refine and instructor's refine are performed in this stage. By the end of this part, each group performs his work by presenting it to all other groups.

Skills: The most important skills to be gained, applied, and/ or improved by the students through the whole wheel are communication, imaging, categorizing, using formulas, constructing diagrams, comparing, solving problems, developing, and sharing. The skills of instructor were questioning, listening, lecturing, assessing, and sharing.

Wheel (2): The main concept of this wheel is "Alternatives".

Subject: Present and annual worth analysis.

Objective: Comparing and selection of engineering alternatives on a base of present worth analysis.

Essential question: Which criteria and guidelines would you follow to compare and select between alternatives on present worth basis?

Activities:

Quadrant (1) {Connect-Attend}: The instructor tried to connect experience of students with the concept through group discussion about their understanding of a team wins in sport game and students succeed in a university course. Attending the students to the concept was performed via rally share to give differences of winning a game and succeeding in an exam. The instructor gives questions to clarify the concept and help students to get the concept.

Quadrant (2) {Imagine-Inform}: In order to imagine the concept of alternatives, students were asked to represent the concept of alternatives and selection process by drawing sketches. The bridge of the general concept of alternatives is the decision of selection between alternatives such as buying a house or renting one. The instructor presented lectures through power point presentation of the contents: Mutually exclusive and independent projects, present worth and annual worth analysis – study period method of analysis - Least common multiple (LCM) method of analysis. Also tree diagram for selection considerations was presented.

Quadrant (3) {Practice-Extend}: Practicing the given information is conducted by given exercises to solve and compare between alternatives on economic bases. Students work in groups to compare between projects by applying study periods and LCM. Furthermore, students work in pairs to select from independent alternatives based on present worth analysis.

Quadrant (4) {Refine - Preform}: To refine their new experiences, the students worked in groups to create their own mind maps of the whole unit. Presentations were introduced and the best mind map had been chosen to be showed in the department.

Skills: The most important skills to be gained, applied, and/ or improved by the students through the whole wheel are communication, defining, and selecting, analyzing, comparing, using formulas, constructing diagrams, practicing problems, developing, and sharing. With respect to instructor the most important skills are communication, listening, managing groups, lecturing, sharing and evaluation.

Examples of questions during the teaching of present worth

analysis by 4MAT are as follows:

1. From your point of view, which project belongs to mutually exclusive and which belongs to independent ones?
2. In your opinion, in order to select among alternatives, which criteria can be applied? Then, by asking the following more detailed questions one by one, and the students were asked to write their answers on a paper.
3. In order to select from an equal life alternative, which criteria should be applied?
4. In order to select from different life alternatives, which methods can be used?

Statistical analysis

The data were statistically analyzed using SPSS22 software. A significance level was set to 0.05 since it is the most used value in educational studies. The independent sample t-test was used to find out the effect of 4MAT on students' learning concepts of present and annual worth analysis.

RESULTS AND DISCUSSION

The pre-tests were conducted before starting the experimental application. The results showed no significant differences between the experimental group and control group in the students' attitudes towards engineering economy ($t=1.401$; $p=0.193$) and their knowledge levels on foundations of engineering economy and present worth analysis ($t=1.013$; $p=0.312$). These results proved that both the experimental group and control group have homogeneous structures. For the post-test, there was statistically significant difference in favor of the experimental group compared to control group at $t=3.180$ and $p=0.002$. In terms of foundations of engineering economy and present worth analysis, the mean of success points of the students in the experimental group was higher than the control group as shown in Figures 4 and 5 as well as in Table 4.

The obtained results showed that 4MAT method provides a positive effect to the success compared with the traditional method. These results support the results obtained by many studies such as Appell (1991), Ursine (1995) and Jackson (2001). Furthermore, the results are supported by the previous related works applied on other science courses such as:

1. Sung-Young and Chang (2005) who considered a teaching method based on the differences between right and left sides of the brain, and tested its effect on

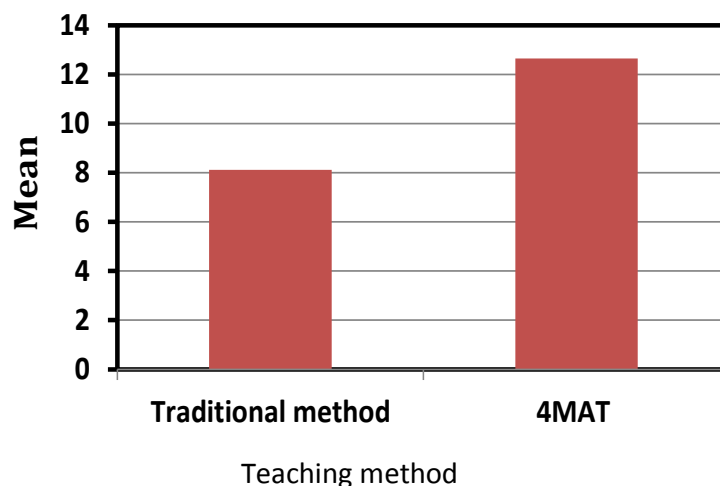


Figure 4. Comparison of traditional method and 4MAT method in terms of mean of success.

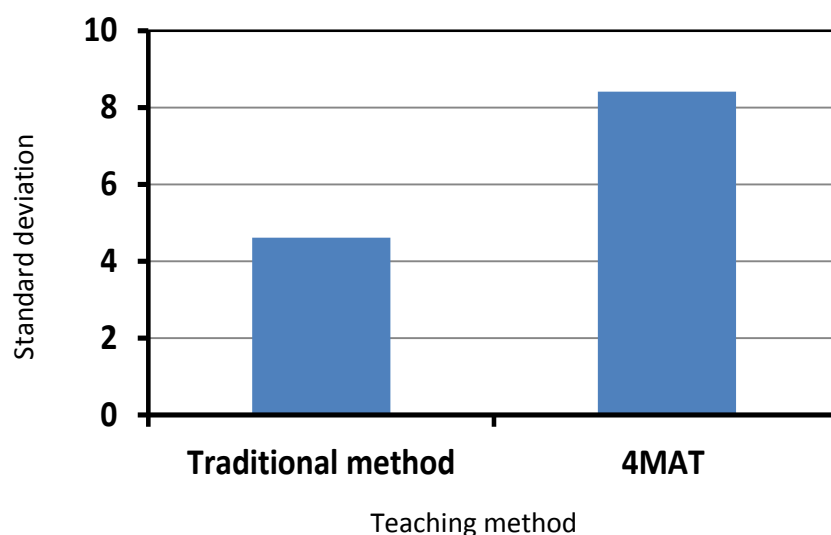


Figure 5. Comparison of traditional method and 4MAT method in terms of standard deviation.

Table 4. Statistics of post-test (knowledge level of the students).

Group	Group size (n)	Mean	Standard deviation	p	t
Experimental (Application of 4MAT)	45	12.65	8.41	0.002	3.180
Control (Application of (Traditional Teaching)	35	8.12	4.61		

Maximum score of this test is 30 points.

creativity and science achievement. The results of teaching by a method based on the bilateral brain characteristics were positive when compared with the results of the traditional method.

2. Shorman (2006) who compared a McCarthy-based and a conventional teaching method to find out their effect on primary eighth graders' acquisition of scientific concepts.

3. Dogar et al. (2008) suggested that the right brain would be beneficial for the students' achievements.
4. Qudah (2009) who studied the effect on science achievement by a teaching method based on McCarthy model comparing with conventional method.
5. Bawaneh et al. (2011) who showed the superiority of Herrmann whole brain teaching method (4MAT) over the conventional one for teaching electric circuits.

Conclusion

In this research, effectiveness of 4MAT method on academic achievement and attitudes toward engineering economy for undergraduate students was investigated. Materials appropriate to the 4MAT system have been prepared for the units of foundations of engineering economy and present worth analysis. A comparison between 4MAT method and traditional method of teaching has been conducted through experimental application. Engineering economy attitude scale and knowledge test were applied. Consistent with the obtained results, it can be concluded that 4MAT method of teaching is more effective than the traditional lecturing method in teaching undergraduate students. The recommendations are shown below, which are considered to be useful for all educators primarily including the engineering economy instructors and the researchers who are interested in the studies of undergraduate students. The learning styles should be applied to all levels at the university education year. Thus, the lecture presentations must be prepared by taking into account these styles. Teaching techniques activating both hemispheres of the brain must be applied for more efficient education in engineering courses.

In order to improve cognition, perception, and affection skills during problem solving in engineering economy, the whole brain must be brought into balance. A specific education for the instructors may be provided to perform a teaching in which both the learning styles and the two sides of the brain are taken into account. Proficiency teaching and training must be delivered to them where these concepts will be taught.

Conflict of interests

The author(s) have not declared any conflicts of interest.

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