Application of Weighted Objective Method in Searching Appropriate Teaching Aids for Lecturing Column Buckling in Mechanical Engineering Department of Andalas University

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Abstract: This paper shows how the appropriate teaching aid was selected in lecturing column stability (buckling), which is considered as the most challenging topic in the subject of Strength of Materials in Mechanical Engineering Department of Andalas University. However, most students are not interested in this topic as it contains a number of mathematical derivations. Teaching aid such as a presentation of materials and figures taken from reference books are not able to stimulate student's interest in the topic. In order to select the best way to explain theoretical concepts without making students bored, the teaching staffs are suggested to use the teaching aid which can stimulate the curiosity of students. For this reason, this paper describes how to use a weighted objective method in determining appropriate teaching aids for the intended topic. The method is usually applied based on several criteria of evaluation, decided by both students and teaching staff. The criteria should be able to fulfill all the demands of the students and the teaching staff. The selected teaching aid theoretically should be able to increase students' curiosity and understanding of students about the topic.

1 INTRODUCTION

The Strength of Material is one of the compulsory courses which is offered by a curriculum of bachelor degree program of Mechanical Engineering Department of Andalas University. It has 3 credits and has 12 topics. According to the survey given to the students, the most challenging topic in this subject is the column buckling. The main reason for this fact is that the topic has too many mathematical derivations. Besides, most students are not good at mathematics. On the other side, the current teaching aids, such as material presentation and reference books are still traditional aids; they are not able to stimulate students' interest in this topic.

In addition, the class size which is big also made the situation worse. That is why in the current situation, the class is quite boring for some students. Most of the science teachers do not pay attention to scientific and technological methods, and this reflects the difficulties that are teaching science (Nasab, Esmaelli, and Sareem, 2015). Since 75% of learning is learned by sight and vision, therefore the use of technological teaching aids are considered very efficient to achieve student's attention.

Shabiralyani (Shabiralyani, et.al, 2015) explored the opinions of selected teachers on the use of visual aids as a motivational tool in enhancing students' attention in reading literary texts in the district of Dera Gazi Khan. The results show that 70% of the students and teachers agree that the visual aids help in motivation; 75% agree that they help in clarification of contents under researching; 68% agree that they increase the vocabulary; 82% agreed that they help save the time in preparing the lessons; 71% agree that they help avoid the dullness; and 92% agree that through visual aids the direct experience increased to observe the things.

Although there are many works have been done related to the effectiveness of the use of teaching aids in teaching, there is still a few works which investigate how to select the best teaching aid among many available aids. Edward (2008) used four specific criteria to evaluate learning resources. The criteria are content, instructional design, technical design, and social considerations. The criteria are intended to encourage teaching staffs to think critically about the resource and evaluate some of its more detailed aspects. Andambi and Kariuki (2013) describes several criteria for selecting relevant

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learning resources by teachers of social education and ethics in Bungoma District, Kenya. However, the selection was done only for available learning resources, and the main criteria are based on the relevancy of teaching resources with the subject of the lecture.

This paper focussed on how to select an appropriate teaching aid for a lecturer to teach column stability. The aim is to select the best teaching aid to stimulate students' interest in the topic and to involve the student's role when the aid is used. In order to understand this current problem properly, two quick surveys were given to the students. The first is aimed to see the students' level of understanding to the topic of column buckling. The data are taken from the students who took a subject the Strength of the Material in even semester 2017/2018. The result of this survey is given in Fig.1, showing that about 61.5% of the students are in the medium, weak, and very weak level of understanding. Only 38.5% of the students are in good and very good level of underst . It means that in general the course outcome is not reached yet.

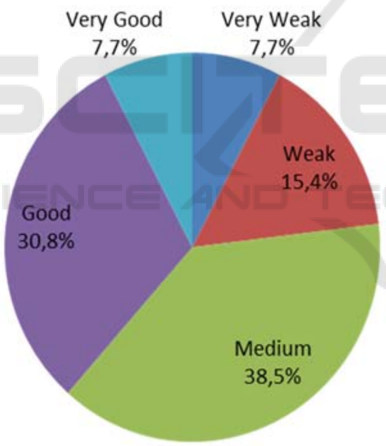

Figure 1: Level of understanding of students for the topic of column buckling.

The second survey is aimed to determine which area of the topic of structural stability is considered very difficult for the students. Fig. 2 shows the list of difficult sub-topics chosen by students in understanding the concept of column buckling. The result shows that the six sub-topics with the number of choices greater than 50% of the total survey are: Q3 (76.9%), Q10 (76.9%), Q7 (69.2%), Q8 (61.5%), Q5 and Q6 (both are 53.8%). The detail description of sub-topics can be seen in Fig. 2. Based on this condition, the criteria of teaching aid should be based on these 6 sub-topics. Other criteria, from the perspective of the students and the teaching staff, are discussed later.

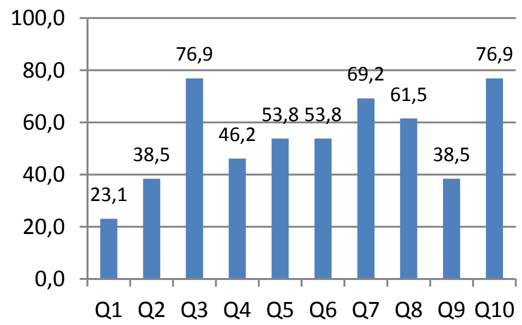

Figure 2: List of difficult topics chosen by students in understanding column buckling.

- Q1. How does column buckling occur?
- Q2. How to calculate the theoretical and critical buckling load?
- Q3. How to determine the mode shapes of buckling?
- Q4. How the geometrical sizes and shapes affect the critical buckling load?
- Q5. How to determine the direction of buckling?
- Q6. :How the types of support can affect the critical buckling load?
- Q7. How the geometrical imperfections can affect the critical buckling load?
- Q8. How the eccentricity of load can affect the critical buckling load?
- Q9. How to determine the minimum length of the column that create the buckling?
- Q10. How to use the standards such as CRC, AISC in determining the critical buckling load?

As a number of criteria must be considered in this selection, it is essential to have a specific method for evaluation. This method should be able to guide the selection for the best result. Thus, this paper adopts a weighted objective method (WOM), a well-known method for evaluation solutions in the procedure of design, to evaluate all the used criteria in the design process. WOM is frequently used to evaluate several alternatives and to select the best alternative based on several evaluation criteria (Diaz and Diaz, 2015; Kota and Chakrabakti, 2007; Hongjiu and Yanrong, 2015)

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2 METHOD AND GENERATING ALTERNATIVES

The method of weighted objectives aims to compare the utility values of alternative designs, by performance against differentially weighted objectives [8]. The procedure is as follows: (i).list design objectives or evaluation criteria, (ii). Rank order the list objectives, (iii). Assign relative weightings to the objectives, (iv). Establish performance parameters or utility scores for each of objectives, and (v).calculate and compare the relative utility values of the alternative designs and multiply each parameter score by its weighted value. The best alternative has the highest sum value comparison and discussion of utility value profiles may be a better design aid than simply choosing the best.

There are three types of alternatives of the teaching aids which are selected: 3D_Model, Program_Simulation, and Poster, as shown in Table I. The 3D_Model is a prototype of a column structure under axial loading, the Program_Simulation is result of a computational program in the form of animation and video, and the Poster is a group of figures or pictures with a simple explanation about the characteristics of column buckling.

Table 1: Types of Alternatives to Solution

Types	Description
3D_Model	3D Real Model of Column
Program Simulation	Video and Animation from Numerical Program
Poster	Pictures/ Figures

3 RESULT AND DISCUSSION

3.1 Evaluation Criteria

The general criteria are taken from some considerations in the perspective of students, lecturers, and easiness of design process. The best method to derive the criterion of evaluation is through the application of the objective tree method (OTM). The OTM offers a clear and useful format for such a statement of objectives (Cross, 2000). It shows a diagrammatic form how different objectives are related to each other, and the hierarchical pattern of objectives and sub-objectives. The procedure of this method is listed as follows: (i) prepare a list of design objectives, (ii) order the list into sets of higher-level and lower-level objectives, and (iii) draw a diagrammatic tree of objectives showing hierarchical relationship and interconnections.

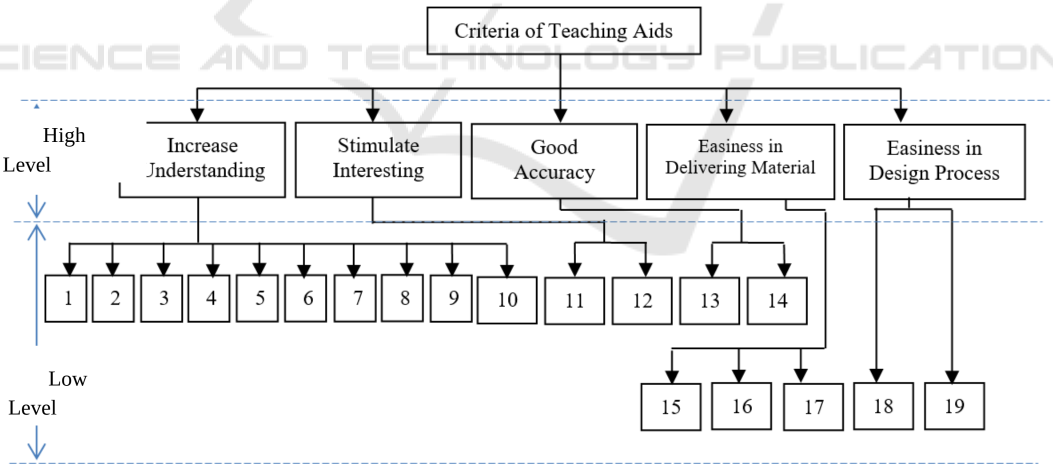

Fig. 3 Finding EC through the application of the objective tree method

Tabel 2. Criteria of Evaluation of Teaching Aids

No.	Perspective	Criteria of Evaluation (High-Level Objectives)	Sub Criteria of Evaluation (Low-Level Objectives)	Rank	Weighted Factor (%)
1.	Students (60%)	EC1: Ability to Increase Student's Understanding (50%)	SC1. How does buckling of the column occurs? SC2. How to calculate the theoretical critical buckling load? SC3. How to determine the mode shapes of buckling? SC4. How do the geometrizal sizes and shapes affect the critical buckling load? SC5. How to determine the direction of buckling? SC6. How the types of support can affect the critical buckling load? SC7. How the geometrical imperfections can affect the critical buckling load? SC8. How the eccentricity of load can affect the critical buckling load? SC9. How to determine the minimum length of column that create the buckling? SC10. How to use standards such as CRC, AISC in determining the critical buckling load?	1	2% 4% 6% 4% 2% 6% 6% 6% 4% 10%
		EC2: Ability to Stimulate Student;s Interesting (10%)	SC11. Interesting Appearance SC12. Easy to Understand	4	4% 6%
2.	Teaching Staffs (32%)	EC3: Good Accuracy (20%)	SC13. Good in accuracy SC14. Easy to show the basic phenomena of buckling	2	10% 10%
		EC4: Easiness in Delivering Material (12%)	SC15. Easy to use SC16. Safe to use SC17. Easy to bring and operate	3	4% 4% 4%
3	Design Process (8%)	EC5: Design Process (8%)	SC18. Easy to make SC19. Cost	5	4% 4%
	Σ=100%	Σ=100%			Σ=100%

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Figure 3 shows 5 criteria (EC) of evaluation (as higher-level objectives). They are (i) ability to increase student's understanding; (ii) ability to stimulate student's interesting; (iii good in the accuracy, (iv) easiness in delivering material of lecture, and (v) easiness in the design process. From these five criteria, 19 sub-criteria (SC1-SC19) of evaluation, as lower-level objectives, to evaluate the appropriate teaching aid is derived. Ten sub-criteria is from the derivation of EC1, two from EC2, two from EC3; three from EC4; and two from EC5. A detailed description of SC can be seen in Table 2.

3.2 Rank Order of Evaluation Criteria

The next step is to give a rank order for EC. For this purpose, the level of importance of each criterion will be compared to each other. For example, if the first criterion is decided more important than the second one, the first will be given a score "1" while the second will be given a score "0". Then the comparison is continuously repeated for other criterions. In the end, the highest rank order is given to the highest score, as the most important criterion among all criteria. In contrary, the lowest rank order is given to the criterion whose score is the lowest. From Table II, the rank order of EC is started by EC1, EC3, EC4, EC2 and the last by EC5..

Table 3. Simple Method of Rank Order of EC

	EC1	EC2	EC3	EC4	EC5	Total
EC1	-	1	1	1	1	4
EC2	0	-	0	0	1	1
EC3	0	1	-	1	1	3
EC4	0	1	0	-	1	2
EC5	0	0	0	0	-	0

The next step is to give a weighted factor (WF) for each EC. Off course, the highest rank is assumed to have a higher percentage than the lowest one. From Table II, the WF of each EC is 50% for EC1, 20% for EC3, 12% for EC4, 10% for EC2 and 8% for EC5 (totally 100%).

The same procedure is also applied to all subcriteria (SC) for each EC. Therefore, every SC should also have their weighted factor, as shown in the last column in Table II.

3.3 Establish Performance Parameters

For each SC, a scale with a range between 1 to 5 is used as a score of performance. A score of 1 shows the worst condition, 3 shows medium condition, and 5 shows the best condition, as shown in Table IV. Table V shows the description of the performance of each SC and scales to measure the performances. The values later are called 'utility values' (see Tabel VI). The utility value is given based on the performance of evaluated alternatives for each SC. For example, SC-16: Safe to Use, where 3D_Model is given 3 points (medium), Program_Simulation is given 5 points (the safest), and the poster is given 4 points (between medium and the safest).

Tabel 4. Criteria of Evaluation of Teaching Aids

Score	Description
1	Not Understand/Ugly/Most Expensive/ Not Safe
2	
3	Medium
4	
5	Very Understand/Good/Cheap/Very Safe

Tabel 5. Performance Parameters

Score	Description
SC1-10	5: Most Difficult, 3: Medium, 1:Easiest
SC11	5: Most Interesting, 3: Medium, 1:Ugliest
SC12	5: Easiest, 3: Medium, 1: Most Difficult
SC13	5: Very Accurate, 3: Medium, 1:Not Accurate
SC14	5: Easiest, 3: Medium, 1: Most Difficult
SC15	5: Easiest, 3: Medium, 1: Most Difficult
SC16	5: Safest, 3: Medium, 1: Most Dangerous
SC17	5: Easiest, 3: Medium, 1: Most Difficult
SC18	5: Easiest, 3: Medium, 1: Most Difficult
SC19	5: Most Expensive, 3: Medium, 1: Cheapest

3.4 Comparison of Alternative Solutions

The value of each SC is given from multiplication of WF and utility values. Again, if SC-16 is taken as an example, the value 3D_Model is 4%×3=0.12, Program_Simulation is 4%×5=0.20, and Poster is 4%×4=1.6. The same procedure is given for the other SCs. Table VI shows the result of evaluation using the method of WOM. Based on this method, the best teaching aid for lecturing the column buckling is through program simulation, because the relative utility value of this program simulation is the highest among the others. Its value is about 4.18 compared to 3.18 for 3D_Model and 3.56 for Poster, in the scale of 1 to 5.

3.5 Actual Design

Based on the result, the next step is preparing some data for computational programming based on finite element analysis to make a numerical simulation which is later used as a part of lecturing video. This video can show several characteristics asked by EC1 and EC3. Both ECs are criteria of evaluation which cover some technical aspects of column buckling. There are some procedures for this work as generally described in the following section:

(1). Prepare numerical models of the column. It must be in a variety of lengths (slenderness ratios) and also types of cross-sections. This step is prepared for SC4.
(2). Prepare numerical models of a variation of supports for column (pin-roller, clamped-roler, and clamped-clamped). This step is prepared for SC3 and SC6.
(3). Prepare a variety of geometrical imperfections to the length of columns. This step is prepared for SC7.
(4). Prepare a variation of eccentricity loads to the columns. This step is prepared for SC7.
(5). Prepare material properties of the column.

Use a finite element package software to calculate the buckling loads.

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Table 6. The result of Total Grade for Every Alternative solution

Subcriteria of Evaluation (SC)	Weighted Factor (%)	Alternatives of Solution					
		3D_Model		Program Simulation		Poster	
		Utility	Value	Utility	Value	Utility	Value
SC1. How buckling of column occurs?	2%	4	0,08	5	0,1	2	0,04
SC2. How to calculate the critical buckling load?	4%	2	0,08	2	0,08	4	0,16
SC3. How to determine the mode shapes of buckling?	6%	3	0,18	5	0,30	3	0,18
SC4. How the geometrizal sizes and shapes affect the critical buckling load?	4%	2	0,08	4	0,16	3	0,12
SC5. How to determine the direction of	2%	4	0,08	3	0,06	2	0,04
buckling?	6%	4	0,24	4	0,24	3	0,18
SC6. How the types of support can affect the							
critical buckling load?	6%	3	0,18	5	0,3	4	0,24
SC7. How the geometrical imperfections can							
affect the critical buckling load?	6%	3	0,18	5	0,3	4	0,24
SC8. How the eccentricity of load can affect the							
critical buckling load?	4%	2	0,08	5	0,2	4	0,16
SC9. How to determine the minimum length of							
column that create the buckling?	10%	2	0,2	4	0,4	4	0,4
SC10. How to use the standards such as CRC, AISC							
SC11. in determining the critical buckling load?							
SC12. Interesting Appearance	4%	3	0,12	5	0,2	2	0,08
SC13. Easy to Understand	6%	4	0,24	4	0,24	3	0,18
SC14. Good in accuracy	10%	4	0,4	4	0,4	4	0,4
SC15. Easy to show the basic phenomena of buckling	10%	4	0,4	4	0,4	3	0,3
SC16. Easy to use	4%	4	0,16	5	0,2	4	0,16
SC17. Safe to use	4%	3	0,12	5	0,2	4	0,16
SC18. Easy to bring and operate	4%	3	0,12	5	0,2	4	0,16
SC19. Easy to make	4%	3	0,12	2	0,08	5	0,20
SC20. Cost	4%	3	0,12	3	0,12	4	0,16
Skor Total			Σ=3,18		Σ=4,18		Σ=3,56

(6). Convert the results to numerical animation forms using post-processor software.

(7). Compare the results to the variation of standard designs. This step is prepared for SC10.

(8). Use all animations, resulted in figures, result of the comparison to design standards to produce a lecturing video which is very interesting in visual.

(9). Asked students in a group to prepare their data to create their animation.

4 CONCLUSION

Through this paper, the method in how to select the best teaching aid for teaching column buckling in the subject of strength of the material is detailly described. The result shows how the simulation of the program is selected as the best teaching aid based on several criteria given by students, teaching staffs and design process. They are (i) ability to increase student's understanding (weighted factor=50%); (ii) ability to stimulate student's interesting (weighted factor=10%); (iii) good in accuracy (weighted factor=20%), (iv) easiness in delivering material of lecture (weighted factor=12%); and (v) easiness in design process (weighted factor=8%).

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