International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August, 2019

Outcomes Based Technique for Measuring Critical Thinking Ability on Computer Science and Engineering Students

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Abstract: ***Literature clearly indicates that it is possible to develop quantifiable outcomes, such as critical thinking abilities, measure them and communicate student learning achievement of the outcomes, if the instructional and assessment approaches are organized in an effective way. Critical thinking ability of the Computer Science and Engineering students is an active process of skilfully conceptualizing the domain concept, analyzing and evaluating the information. This paper attempts to measure learning outcomes of 'critical thinking ability' which might be obtained by the students of Computer Science and Engineering, through two different instructional perspectives namely, i. the traditional linear time-bound instructions and ii. Outcomes Based instructions. The objective of this exercise is to determine whether Outcomes Based Education (OBE) in its instructional principles would be more suitable over the traditional methods in imbibing 'Critical thinking ability' as a learning outcome? Is it possible to classify students who prefer OBE methods of instructions? The paper elaborates an experimental study to compare and correlate the results obtained by these two selected instructional principles. The conclusions drawn out of the experimental studies as well as from the survey results will be of immense use to educational researchers of Computer Science and Engineering.***

Keywords : Assessing learning outcomes; Critical thinking ability; Holistic rubric; Outcomes Based Education

1. INTRODUCTION

One of the practices recommended by Outcome Based Education (OBE) is to promote group projects and discussions/debates that might promote 'critical thinking' ability. Is it valid to Computer Science and Engineering students? Whether the learning outcome of 'critical thinking' is effective in traditional linear method of instructions too? Whether students who prefer active learning of OBE, be classified? In view of these research questions and the background, this paper presents comparative study reports on the effectiveness in measuring 'critical thinking' learning outcome by these two instructional (and assessing) approaches. The students' samples are restricted to Computer Science and Engineering discipline. Two research methods, namely descriptive survey method and experimental studies have been considered. For the purpose of the study, experimental group consisting of classified students who prefer OBE and the rest of the whole sample as control group have been organized. The proposed experiment is to execute through assignments on the control group, as this is most popular in traditional methods; while sub groups are formed with experimental group sample in measuring the learning outcome of 'critical thinking' through group project (recommended by OBE) on the same problem that was assigned to the control group. The study includes one way ANOVA for comparisons on the specifically designed holistic rubric for qualitatively measuring 'critical thinking' outcome. Conclusions which are drawn out of the experimental studies will significantly contribute to the aspects of instructional methods and continuous formative assessments of OBE in Computer Science and Engineering discipline. This study is a part of a whole research work of the first author.

Revised Manuscript Received on October 30, 2019.
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II. LITERATURE SUPPORT

According to Spady, W. G, (1994), assessing techniques should be result oriented (to determine what the student is able to do/demonstrate) rather than process oriented (test with what the students were taught). Critical thinking is one of the essential attributes of OBE (Killen, R, 2007). Zivcovica, S (2016) insists that specific teaching approach is needed which employs critical thinking, so as make the students to think critically and analytically, and the students should be able to solve real-world problems effectively. Effective communication is also stressed for 'critical thinking'. Group discussions and projects are instructional strategies that imbibe 'critical thinking', as debating real world problem through effective communication is encouraged by these approaches. The average number of group (mini) projects (carried out through group discussions) being practiced in Kerala state in India is although less in numbers, but is comparable with a few developing countries around the world (Bruce Mathew et. al. 2018). Group discussion could be one of the portfolios for facilitating continuous formative assessments of students, an important requirement of OBE. Besides, in the case of assignments, a portfolio for assessments is practiced in traditional linear method of instructions. *Group work is very effective in motivating students that will enhance their employability skills* (such as critical thing ability), as it is built on constructivist principles (Bruner, 1986).

Even though many students enjoy group discussion, it might be challenging to some (Ruth Ayres, 2016). This may be due to the lack of experience. This is what this paper's researcher has found from the oral discussions held with some of his own students.

The same author (Ruth Ayres, 2016) has insisted that for group works to be more effective, it is important to outline the purpose of group activities (like the development of critical thinking ability for a specific domain problem). Tutor (or the researcher) could randomly select the groups (Ruth Ayres, 2016) and for projects that require huge tasks, smaller group size is preferable, with a maximum size be about 15.

III. METHODOLOGY AND SAMPLING

The methodology adapted in this research project consists of two techniques: i. Survey method for classifying the students (as experimental group) who are inclined to OBE and ii. Experimental method is designed to validate the apt measurement for 'Critical thinking ability'. Accordingly descriptive study is done using the survey for the classification of the experimental and control groups of students according to traditional or OBE preference of the students' sample. For the experimental method, design and administer a rubric for measuring 'critical thinking' ability through a) Group discussions as per OBE's principle and b) Assignments as popularly practiced in traditional method have been done.

Total no. of students' size, as per purposive sample (Sharma B.A.V., 1988): **110**. Design basis: Scale value of the questionnaire (Felder, R. M, et. al. 2016) for 'Teacher-led' = **1**; for 'Learner-centred' = **2.** No. of questions considered = **7**. The demography consists of well mixed representation of gender, years of study (Computer Science and Engineering) of the (three distributed) regions in central Kerala.

Questionnaire and score values (7 questions):

Q(1): Learning through 'Thinking (1)' or by 'Doing (2)';
Q(2): Treating self as 'Realistic (1)' or 'Innovative (2)';
Q(3): Recalling by 'words (1)'; or by 'picturing (2)';
Q(4): Clarity in comprehending 'details more than overall structure (1)' or 'overall structure more than details (2)';
Q(5): 'Think about (1)' or 'talk about (2)' newly learnt material;
Q(6): Teacher should teach 'ideas & theories (1)' or 'facts & real life situation (2)';
Q(7): Prefer new information through 'verbal / written (1)' or 'pictures / drawings (2)'. The option (2)s are closely associated with OBE while option (1)s refer to the traditional linear method (Killen, R, 2007) of instructions.

The statistical results of the completed survey from the above sample are presented in Table - I.

Table-I Statistical Descriptions obtained from Survey for Group Preference

		Q(1)	Q(2)	Q(3)	Q(4)	Q(5)	Q(6)	Q(7)
N	Valid	110	107	108	110	109	110	110
	Missing	0	3	2	0	1	0	0
Mean		1.7364	1.3364	1.8981	1.5636	1.2844	1.8182	1.7455
Median		2.0000	1.0000	2.0000	2.0000	1.0000	2.0000	2.0000
Mode		2.00	1.00	2.00	2.00	1.00	2.00	2.00
Std. Deviation		.44262	.47472	.30386	.49820	.45321	.38746	.43760
Variance		.196	.225	.092	.248	.205	.150	.191
Minimum		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Maximum		2.00	2.00	2.00	2.00	2.00	2.00	2.00

The consolidated responses (frequencies) are presented in Table-II. The results of both Tables 1.0 and 2.0 indicate that most of the students have opted for option (2), which refers to OBE's recommended practices for the questions 1, 3, 6 and 7, while fewer of them have opted for (1) the Traditional method for the questions 2 and 5, and the responses for question 4 were found to be not significantly differing between OBE and traditional method. Table 1.0 show the values of variances, the deviations relative to the means of the central tendencies, which are found to be small. The standard deviations (square roots of the variances) are also present in the table so as to have a relatively normalized view of the deviations.

Table-II Frequencies of Responses

No Of Students Responded	Q(1)		Q(2)		Q(3)		Q(4)		Q(5)		Q(6)		Q(7)	
	Traditional (1)	OBE (2)	Traditional (1)	OBE (2)	Traditional (1)	OBE (2)	Traditional (1)	OBE (2)	Traditional (1)	OBE (2)	Traditional (1)	OBE (2)	Traditional (1)	OBE (2)
freq	29	81	71	36	11	97	48	62	78	31	20	90	28	82

Observation: The results of both Tables I and II and also the oral interactions performed by the researcher and the respondents, indicate that some of the instructional practices of OBE have not been actually tried out by the teachers (like the exposition of holistic picture to the students or presenting an overall structure of a concept), rather the teachers hitherto were providing only the details, as put forth in question (4). This agrees with the literature reported (Ruth Ayres, 2016). More acceptances on OBE (responses) are seen for apparent items; whereas it is not so for questions 2 and 5; as the OBE's practices had not been tried out in the teaching-learning processes by the teachers, hitherto. In view of this finding, both these aspects (variables 2 and 5) have been selected for experimenting with the students. However all the variables of the questionnaire are yet needed for a correlation study, so as to determine whether all the questions (variables) truly convey OBE to the respondents or not? The correlation results (Pearson's factors) are presented in Table III.

Table III Correlation Study on the Questions

	Q(1)	Q(2)	Q(3)	Q(4)	Q(5)	Q(6)	Q(7)
Q(1) Sig. (2-tailed)		.847	.409	.475	.553	.037	.073
Responded	110	107	108	110	109	110	110
Q(2) Sig. (2-tailed)	.847		.117	.939	.026	.835	.467
Responded	107	107	105	107	106	107	107
Q(3) Sig. (2-tailed)	.409	.117		.893	.178	.435	.022
Responded	108	105	108	108	107	108	108
Q(4) Sig. (2-tailed)	.475	.939	.893		.568	.177	.097
Responded	110	107	108	110	109	110	110
Q(5) Sig. (2-tailed)	.553	.026	.178	.568		.476	.618
Responded	109	106	107	109	109	109	109
Q(6) Sig. (2-tailed)	.037	.835	.435	.177	.476		.959
Responded	110	107	108	110	109	110	110
Q(7) Sig. (2-tailed)	.073	.467	.022	.097	.618	.959	
Responded	110	107	108	110	109	110	110

It is found (Table 3.0) that Q(1) is correlating with Q(2) and Q(5); Q(2) is correlating with Q(4) and Q(6);Q(3) is correlating with Q(4); Q(4) is correlating with Q(5); Q(5) is correlating with Q(7); Q(6) is correlating with Q(7), as the values of these pairs are found to be more than 0.50 (Table 3.0). Hence the questionnaire is acceptable as true representation for distinguishing OBE from the Traditional method. From these two groups (experimental and control) the experiments is tried out.

IV. EXPERIMENTAL SETUP

The average number of students who had responded (preferred) for OBE's method is found to be around 68(roughly the average of those preferred for (2)). Hence these 68 respondents have been selected as sample size for the experimental group (sub divided into three sub groups consisting of 24, 20 and 24 participants for the purpose of conducting group project and discussions). While for any huge project, smaller group may be preferable(size could be 15, Ruth Ayers, 2016); but due to the large size of experimental group and the selected experimental project itself is small in nature, the authors of this paper preferred to adapt convenient sampling with almost equal number of distributions, like 24, 20 and 24 as sub groups. Besides, it will be difficult to report learning outcomes when the group size is large for larger projects and technological support may be required for such situations (Carriveau, 2016). Hence the authors have chosen convenient sampling for this sub grouping. Out of the remaining 42 respondents, 8 had dropped out from the proposed experiment and the control group size has now become 34. Control group is however not going to practice group discussions, but assignments. However, with the help of senior students it was possible to measure the rubric value with sub group sizes varying from 20 to 24 and also for assessing the assignments with the help of the same rubric.

Innovation (Q(2)) and Talking (articulating) about what was learnt (Q(5)) are the two aspects that the respondents did chose, due to non-familiarity with OBE (as confirmed from the oral interactions had with them by the researcher). Combining these two aspects (Q(2) and Q(5)) and fitting them into one single outcome, has pointed to 'Critical thinking' ability; which is a metric of OBE (Haidar M. H, 2017). One of the metrics of 'Critical thinking' is to measure the ability for articulating domain content as per the definition(published and found in literature) of an outcome; and by the usage of appropriate phrases / language of 'critical thinking': compiled by several works (GnanaSambanthan, et. al. (2018),Jonassen, D et. al. (1997),Marzano R. J, et. al. (2007); Merrill M. D (2002)).

The domain dependent problem for the proposed experiment (Maurice J. Bach, 1986) has been chosen from the area of 'Operating System', which requires critical thinking ability to comprehend and debate on the chosen problem. The problem is pictorially presented in Figure 1.0.

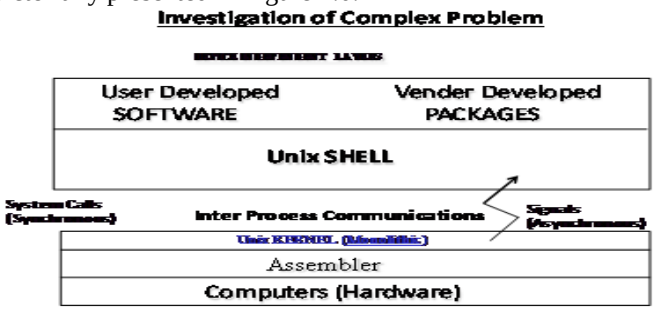


Figure 1.0 Diagram that indicates Domain Problem which requires Critical Thinking

Figure 1.0 shows a typical concept of Computer Science and Engineering course, namely the Operating System. The question put forth on this chosen domain is "*Argue why popular virus attacks would probably be unsuccessful in Unix O.S"*? as per Figure 1.0 (clue). The answer could be a description of a concept in the form of a report, that could be submitted either through group discussions by the participants of the experimental group (3 sub groups) and through assignments submitted by the control group.

Samples of the outcome phrases (or equivalent/similar) that are rhetoric to the domain for the chosen concept: [In group discussions] ---is the most effective way to----;----is the decision made based on -----; ---statement / idea that best represents ---;---is the
main / biggest problem when / that---; ---is / are the appropriate / proper procedure for---; ---is / are the procedure that is / are used; ----is the correct way / method to...; ---are the effects of / when ---; --- probably would happen if-- etc.
[In assignment reports] Explained / not explained how best to deal with conflicting information; Recognized ----- that is relevant to ----issue; Provided ------ as rationale for a decision and included why it was best/better than another decision etc.

The researchers had looked for these or similar phrases or equivalent from the reports; or the usages in the debates of group discussions, using the rubric (Table IV) for measurement.

V. RESULTS AND DISCUSSIONS

Measurement of the competencies from group project/discussions is done through proper design of a holistic rubric descriptors (Peter A. F, et. al. (1994)).The selected learning outcome (Jonassen, D et. al. (1997)) is '*Articulating content*' for measuring 'critical thinking'; by considering the appropriate phrases / interrogation words (Marzano, R. J, et. al. (2007). The holistic rubric shown in Table IV is designed for measuring qualitatively the 'critical thinking' ability obtained by the students. Evaluation on this competency (outcome) from the assignments (control group) was done on the aspects namely: the language representing 'critical thinking' including the usage of interrogative words or similar and also the reliability and validation of their responses. Scores obtained, on these aspects from the group discussions separately by the three sub groups participated, are then compared with the control group's assignment results. These statistical data are presented in Table V. The Cronbach's Alpha was found to be 0.757, which is acceptable as reliable. The various descriptive statistical data for the assignment (control group) are also presented in Table V alongside the experimental group. The same rubric descriptors (presented in Table IV) which were adapted for the qualitative measurement of group discussions were also adapted for both the control group's assignments.

Table IV Rubric for measuring 'Critical Thinking'

Score / Criteria	**Mastery (5)**	**Highly competent (4)**	**Competent enough (3)**	**Elementary (2)**	**Novice (1)**
Quality of articulations	Articulated a thorough knowledge heuristically in interrogations	Related to understandable working knowledge	Related to Basic knowledge	Articulations were vague about the knowledge	Articulations were unclear about the knowledge

Table V Statistical Descriptions obtained from the Experiment

Descriptions	Experimental Sub Groups			Control Group
	Group 1	Group 2	Group 3	
Valid	24	20	24	34
Mean	3.6667	3.4000	4.2083	1.2647
Median	4.0000	4.0000	4.0000	1.0000
Mode	4.00	4.00	4.00	1.00
Std. Deviation	1.12932	1.18766	.72106	.51102
Variance	1.275	1.411	.520	.261
Minimum	1.00	1.00	3.00	1.00
Maximum	5.00	5.00	5.00	3.00

As explained with the Table 1.0, the standard deviations (square roots of) and variances of the three sub groups (Table 5.0) are found to be around 1.0 (in the three columns of Table 5.0 meant for experimental group) which could arguably be accepted, as found in any group discussions, the contributions of individual participant might vary. However, the low value of the standard deviation seen for the control group (about 0.5) indicates that most of the students who had submitted the assignments did not deviate from each other (last column of Table V) in their performances.

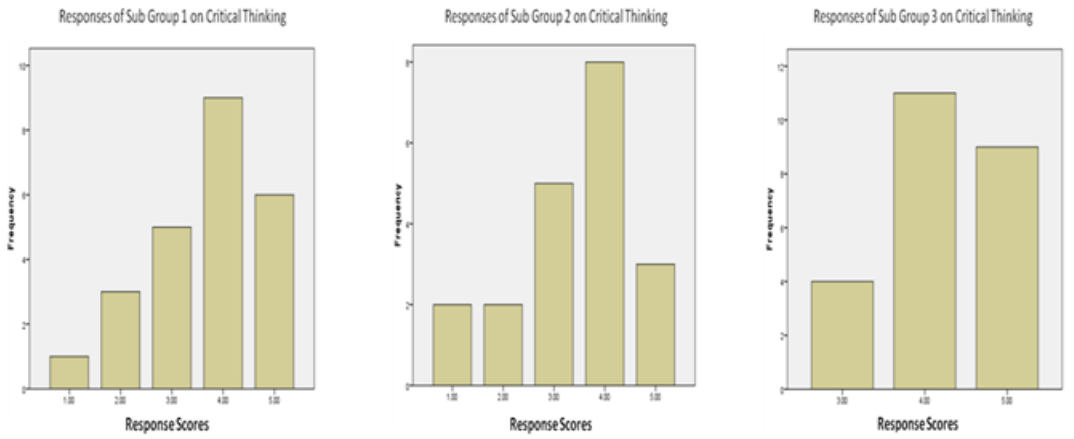
The performances of sub groups of the experimental group are pictorially shown in Figure 2.0.

(Carriveau, 2016) states that any score related to a rubric value is obtained first, and then the measure of the students' attainment of that outcome at a group level could be calculated. Accordingly the observation is made.

Observation: The results show (Figure 2.0) that the scores of most of the students of the experimental group, who participated in group discussions (sub groups 1, 2 and 3 are shown from left to right of the Figure 2.0) have performed well as per the rubric scores of Table IV. In fact the median value and the mode value of all the three sub groups (Table V) are found to be 4.0. The maximum score of 4.0 of the rubric scale can be accepted as many students are found to be of highly competent.

This shows that group discussion would work well for developing and measuring 'critical thinking'.

Significant variation is found within the sub groups, as 'F'



not significantly different from 'F critical' (Table VI).

Figure 2.0 Rubric Scores of Experimental Sub groups

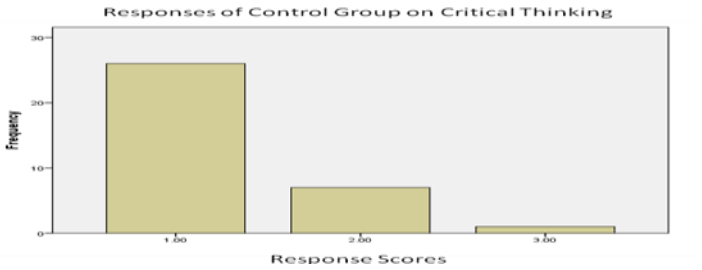


Figure 3.0 Rubric Scores of Control group

But it is not the same observed from the control group of students, as seen in Figure 3.0. Not even a single student has scored the higher score of 4.0 or 5.0. In fact the average score is found to be the lowest, namely 1.00 as per the last column of Table V. This indicates that the traditional method of teaching could not imbibe 'critical thinking' ability. This is further validated from the study of significant difference between the two groups' performances.

Table VI provides the results of one-way ANOVA computed between the performances of sub groups of the experimental group. Table VII provides the results of one-way ANOVA computed between the performances of experimental group from control group.

Table VI. One-way ANOVA results for Within Experimental Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.400	4	.850	.613	.660
Within Groups	20.800	15	1.387		
Total	24.200	19			

Table VII One-way ANOVA results for Experimental and Control Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.633	1	1.633	1.297	.267
Within Groups	27.700	22	1.259		
Total	29.333	23			

There is a significant difference found between the experimental groups and the control group, as 'F' value is significantly greater than 'F critical' (Table VII). From these studies important conclusions are drawn.

VI. CONCLUSIONS

Computer Science students can be classified into a group of those who are inclined to Outcomes Based Education (OBE), determined through appropriate surveys and feedbacks and they will be ready for effectively learning through OBE's principles and norms, better than the traditional students, particularly in obtaining learning outcomes like 'critical thinking' ability.It is concluded that articulating a domain dependent content for a critical situation, an important metric for 'critical thinking' ability of OBE, will be more effective in group projects / discussions of the OBE's principle, than that of conventional assignments practiced in traditional methods of instructions.

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Dr. T Gnana Sambanthan, ME, PhD is a pioneer in the area of outcome based education. He was a professor in the department of computer science at NITTTR, Chennai,), a centrally funded Institution of the Ministry of Human Resource Development, Govt. of India, in Chennai. He has obtained a blend of Industrial, Research and Teaching/Training experiences of several years from India and abroad. He also had a two years stint with the state council for Science & Technology coordinating Industry-Institute-Interaction cell. He has produced 13 PhDs and his area of interest include concept-based extractions, grid computing, Instructional Design and E-Learning.