Effect of Guided Discovery Teaching Method on Students' Performance in Science in a Collaborative Learning Environment
by

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Abstract

This study examined the effect of guided discovery and regular 5E teaching methods on Science achievement of grade 9 students. A quasi-experiment included a pre-post test design with a non- randomized treatment group and 5E regular teaching method as a control group was used in this study. Two Tamil medium National schools located in Colombo district were selected using a criterion sampling technique. A sample of 147 grade 9 students (75 males and 72 females) was drawn from their respective intact classes out of ten classes. Researcher-made Science Achievement Test comprised of 20 multiple choice questions was administered before and after the treatment to measure the level of student's achievement in Science. The reliability of the tool 0.653 was established using test-retest method. The data were analyzed using Analysis of Covariance (ANCOVA). The results showed that the guided discovery teaching method was most effective in improving students' performance in science. The adjusted R squared value indicated that approximately 63% of the total variance in the posttest scores was accounted for by the teaching methods used in this study. The difference between the achievements of male and female students taught with guided discovery and regular 5E was statistically significant. Males outperformed females on science. Also there existed a statistically significant difference in achievement among the high, medium and low achiever groups in the experimental group. High achievers benefitted more when taught with guided discovery method, than medium and then low achievers. It is recommended that science teachers should undergo extensive in-service training for effective implementation of 5E learning cycle.

Keywords - Achiever groups, Collaborative learning environment, Guided discovery, Science achievement

I. INTRODUCTION

Science is meaningful and interesting to learn when it utilizes the real-life situations to promote the understanding of concepts. Provision of maximum opportunities to student for interacting productively with the real-life situations has been the main focus of teaching science [1]. To attain this goal, students should understand and appreciate the various processes of science. Recent reform in science curriculum at the secondary level is attempted to shift its focus from teaching content of science to the transformation of students who can think and behave as scientists do by means of incorporating the process of science along with its product. Most scientific endeavors require science process skills such as data interpretation, problem solving, experimental design, scientific writing, oral communication, collaborative work, and critical analysis of primary literature. These are the fundamental skills upon which the conceptual framework of scientific expertise is built. Many educationists and educational psychologists consider "incorporating the best method of teaching the

process of science that would facilitate scientific knowledge to be constructed" as the central concern of a science teacher [2]. The teachers should teach inductively in addition to deductive methods thereby encouraging students to actively engage in the learning process to discover new rules and ideas to construct his/her own knowledge based on prior knowledge rather than simply memorize rules and ideas that the teacher presents [3,4].

The change in the views of teaching science through guided discovery method has its root in Bruner's work on discovery learning. Numerous studies have asserted the effect of guided discovery method on science achievement of secondary students [5, 6, 7, 8, 9, 10, 11]. In the guided discovery teaching method learner receives problems to solve, but the teacher provides hints and directions about how to solve the problems to keep the learner on track. The problems are given along with a systematic succession of questions to aid the student to construct knowledge thus, providing more guidance concerning how to solve the problem [2]. A central strategy for constructivism is to create a collaborative learning environment among the learners [12]. In a collaborative learning environment, learners have the opportunity to extend and deepen their learning experiences, test out new ideas by sharing them with group members and receive critical and constructive feedback.

In Sri Lanka, present reform which was introduced in 2006 at the secondary level is a learner centered and involves activity based learning through 5E learning cycle. The implementation of this model in teaching science is made with the view to encourage students work in groups, scaffolding through talk, progressing on some aspect of a task and to understand a particular concept when he/she struggles work individually. Although the necessity of this instructional method has been widely acknowledged all over the world [13,14], in Sri Lanka the implementation for developing science process skills among the secondary students has become challenging due to insufficient skills [15]. It has been noted that under 5E instructional model, scaffolding has not been used effectively by the science teachers; instead, the method the teachers adopted could be described as a 'pseudo-scaffolding'. Sometimes, to the extreme, due to various reasons including increased number of students in the class, pressure of work and limitations in the time generally available to cover a syllabus prescribed for examination science teachers are compelled to resort to the much easy lecture method of teaching for convenience. This has been reflected on persistent poor performances of secondary students in Science subject [17, 18, 19].

II. PURPOSE OF THIS STUDY

The objectives formulated for the purpose of this study were: (1) to determine the achievement levels of male and female students in science after being taught by guided discovery and the regular 5E methods; (2) to determine the effect of guided discovery and regular 5E methods on students' science achievement scores; (3) to determine the effect of gender on students' achievement scores in science after being taught with guided discovery and regular 5E methods; (4) to examine whether there are any significant differences among high, medium and low achievers' science achievement taught with guided discovery method. In order to achieve objectives two, three and four, the hypotheses tested were; (1) there is no significant difference between the post test mean scores of students taught using guided discovery and the regular 5E methods; (2) there is no significant difference between the post test mean scores of male and female students taught with guided discovery and regular 5E teaching methods; (3) there is no significant difference among the low, medium and high achiever students after being taught with guided discovery teaching method.

Research design

A quasi-experimental type of research was used for the purpose of this study. It was specifically a nonrandomized, non-equivalent control group, pretest-posttest design. Guided discovery teaching method was used as a treatment factor (independent variable with two levels) and the posttest scores of students were considered as a dependent variable. Gender was taken as a confounded variable.

Participants

The study population was made up of 380 students of grade 9 classes of two Tamil Medium National schools located in Colombo district. A sample comprised 75 males and 72 females; altogether 147 students took part in this study. Experimental group comprised 38 male and 36 female students and the control group comprised 37 male and 36 female students. Each school had an experimental as well as a control groups and they were selected from their intact classes. Ninth-grade students were selected because they were assumed to be well adapted to the guided discovery learning environment. The schools were selected using a criterion sampling technique and the following criteria were used for this purpose:

1. Schools that have junior science laboratories very well equipped with scientific apparatuses.
2. Schools that have separate classrooms with adequate spaces to enable the students to work collaboratively.
3. Schools in which the students were not being taught the lessons to be experimented during the study period.
4. The schools that have students with more or less similar demographics.

Instrument

Cognitive achievement of Students in Science was measured using a researcher-developed science achievement test comprised of 20 multiple choice questions with four alternatives. The total score ranges from 0, the minimum to 20, the maximum had been assigned to the test. The items in the test were developed based on the topic, "observes the environment as scientists" that was prescribed under the competency one in grade 9 syllabus. This topic was selected because the study took place in the first term of the school academic year. Initially 25 items were included in the draft and piloting study was done with 29 students who were found to be similar in their ability to the participants to be included in the study. Test re-test reliability was established using Pearson's Product Moment Correlation Coefficient Method and the index of 0.65 was determined. The students in the experimental group who scored above 18 were categorized as "high" achievers; between 15 and 17 as "medium" achievers and below 14 as "low" achievers.

Experimental Procedure

Before introducing the guided discovery teaching method as a treatment to the experimental group, pre test was administered on the experimental and the control groups to determine their prior knowledge on the lessons to be taught. The lessons to teach the students in the experimental group were prepared in accordance with the principles of guided discovery teaching method by the researcher using grade 9 text book and the Teacher Instructional Manual of National Institute of Education. As prescribed in the syllabus, twelve lessons were included in the lesson plans. The teaching period lasted for two weeks. Experimental group consisted of 74 students (38 male, 36 female) has been taught using the guided discovery method by the researcher in a

collaborative learning environment and the control group consisted of 73 students (37 male, 36 female) was taught by the regular 5E method by the respective subject teacher of that class. At the end of teaching period, a post test was administered to test the instructional effectiveness of the two teaching methods.

IV. RESULTS

The statistical tests used in this study were ANCOVA, Levene's post-hoc test for assuring homogeneity of error variance between groups and Bonferroni post-hoc test to perform pair-wise comparisons. Descriptive statistics were used to analyze the pretest and posttest scores. The results of these tests are appeared in the tables given below. Before performing ANCOVA to determine the main effect of methods on achievement, a test for homogeneity of regression was run to assure there was no interaction effect existed between covariate – pretest scores and factor – treatment. The F-ratio shows that the interaction was statistically insignificant, $F(1,131)=1.85, p>0.05$.

Descriptive statistics appeared in Table 1 show the comparison of pretest and posttest scores of students taught with guided discovery and regular 5E methods categorized in terms of gender. The results show that the mean gain score for experimental group was higher than (11.58) the mean gain score for the control group (5.27).

The results of ANOVA on the pretest scores appeared in Table 2 show that the difference between the experimental and the control group is insignificant, $F(1,145) = 1.547$, $p>0.05$, and thus both groups were similar before the treatment. An increase in the scores from pretest to posttest indicated that the guided discovery method had an influence on the improvement of students' score in science compared with the posttest scores of students

taught with regular 5E method. Therefore, it can be said that the difference between the pretest and posttest scores was not due to chance but as a result of treatment.

Table 1: Descriptive Statistics of the pretest and the posttest Scores in terms of Gender and Teaching Methods

Teaching Methods	Gender	No.of Stud ents	Pre test		Posttest	
			X	SD	X	SD
Guided Discovery	Male	38	5.47	1.98	17.68	2.24
	Female	36	5.61	1.32	16.53	2.49
	Total	74	5.54	1.68	17.12	2.42
Regular 5E	Male	37	5.95	1.78	11.92	3.57
	Female	36	5.83	1.70	10.39	2.02
	Total	73	5.89	1.89	11.16	3.00

With regard to the scores obtained after intervention by male and female students of experimental and control groups, the mean gain scores of male (10.94) and female (10.61) students taught with guided discovery method are greater than the mean gain scores of male (6.46) and female (4.47) students taught with regular 5E method. In both teaching methods male students performed better (17.40) than their counterparts (15.08).

The results of ANCOVA performed to determine the main effect of teaching methods on the achievement of students in science are presented in Table 3. As a precursor to the ANCOVA, Levene's test of equality of error variances was performed. The F-ratio of the test show that the difference of error variances between the experimental and the control groups was statistically insignificant at the 0.05 alpha level, $F (1,145) = 2.864$, $p>0.05$. This confirms that the assumption for ANCOVA was not being violated. Thus, both groups were found to be homogeneous.

Table 2: Summary of ANOVA Comparing Pretest Scores for Experimental and Control Groups

	SS	df	MS	F
Between groups	4.5	1	4.5	1.547
Within groups	421.50	145	2.91	
Total	426.00	146		

Table 3: Summary of ANCOVA on Posttest Mean Scores of Students taught with Guided Discovery and Regular 5E Teaching Methods with Pretest Scores as Covariates.

Source	SS	df	MS	F
Pretest (covariate)	194.97	1	194.97	32.26*
Method	1383.21	1	1383.21	228.88*
Error	870.25	144	6.043	
Corrected Total	2357.40	146		

R squared = .631, Adjusted R Squared = .626, *p<0.05

The results appeared in Table 3 show that the F-test model supported the effect of the teaching methods on student achievement in science after controlling for pretest scores as covariates, $F(1,144)=228.88$ p<0.05. The reason for controlling the pretest scores is because it significantly predicted the posttest scores. That is, the covariate, pretest was significantly related to the students' performance in the posttest, $F (1,144) = 32.26$, p<0.05, partial eta squared = 0.183. The difference between the posttest mean scores of students taught using guided discovery and regular 5E teaching methods was statistically significant. Two types of teaching methods had differed significantly in improving students' achievement in science. The adjusted R squared value of 0.626 indicates that approximately 63% of the variance in the posttest scores of students in science subject was accounted for by the teaching methods used in this study.

Table 4: Summary of ANCOVA on the post test mean scores of students taught using guided discovery and regular 5E teaching methods using gender and pretest scores as covariates

Source	SS	df	MS	F
Pre-test (covariate)	195.88	1	195.88	34.99*
Method	1379.29	1	1379.29	246.39*
Gender	69.74	1	69.74	12.46*
Error	800.51	143	5.60	
Total	31902.00	147		

R Squared = .660, Adjusted R Squared = .655, *p<.0.05

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Table 5: Summary of ANCOVA of the Posttest Mean Scores of Students with different Achiever Groups taught with Guided Discovery Method with Pretest Scores as Covariates

Source	SS	df	MS	F
Pretest (covariate)	0.605	1	0.605	0.873
Achiever groups	301.054	2	150.527	217.109*
Error	48.533	70	0.692	
Total	22121.00	74		

R squared = .887, Adjusted R Squared = .882, *p<0.05

The results presented in Table 4 show that the difference between the post test mean scores of male and female students taught with guided discovery and regular 5E teaching methods was statistically significant at the 0.05 alpha level, after controlling the effect of pretest, $F (1,143) = 12.46$, p<0.05. This indicates that the gender effect was significant on students' achievement in science. This ANCOVA test was performed after removing the interaction effect if existed between gender and methods. The results show that the interaction effect was statistically insignificant at the 0.05 alpha level, $F (1,142) = 0.11$, p>0.05.

A one way ANCOVA with a post-hoc test was performed on posttest mean scores of students to determine the effect of achievement levels of students taught with guided discovery method after controlling pretest scores as covariates. The summary of ANCOVA is presented in Table 5. The results show that the difference among the three levels of achievement was statistically significant at the 0.05 alpha level, $F (2, 70) = 217.109$, p<0.05. This indicates that the guided discovery method has an impact on the improvement of scores from pretest to posttest of the students with different ability levels. Bonferroni pair-wise comparison test was run to determine if there were any statistically significant difference existed, where these differences were.

Table 6: Summary of Bonferroni pair-wise comparison test for the posttest scores of high, medium and low achiever groups

(I)AG	AG(J)	MD	SE	95%CI	
		(I-J)		LB	UB
H	M	3.18*	.21	2.67	3.70
	L	6.41*	.29	5.69	7.12
M	H	-3.18*	.21	-3.70	-2.67
	L	3.23*	.29	2.51	3.94
L	H	-6.41*	.29	-7.12	-5.69
	M	-3.23*	.29	-3.94	-2.51

H-High; M-Medium; L-Low' AG-Achiever groups *p<0.05

The results of this test are presented in Table 6. The mean differences show that the achiever groups differed in science achievement. This indicates that there was statistically significant differences among the posttest mean scores of high, medium and low achiever groups of students taught with guided discovery method. Both the observed and adjusted means show that students in the higher achiever group statistically significantly performed best followed by students in the medium achiever group (mean difference, 3.18) and then the lower achievers (mean difference, 6.41) after being taught using guided discovery method.

V.   DISCUSSION

The effect of teaching methods on students' achievement in science

Findings on the effect of teaching methods on science achievement indicated that the students gained significantly more knowledge in the topic taught with the guided discovery method than those who were engaged in regular 5E method. This finding supports the previous studies examining the effectiveness of guided discovery method on science achievement [5,6,7,8,9,10,11].

However, in the previous findings it was not clear about what type of learning environment that the researcher has adopted to teach using guided discovery method. In this study the enhanced performance of students can be attributed to the learning environment within which the students were engaged when they were taught with guided discovery method. Many studies on active learning, asserted that the collaborative learning results in higher academic achievement as compared to competitive or individualistic approaches [16]. The present study also confirmed that the students performed well in collaboration than the regular 5E learning environment.

Despite the small group activities used in regular 5E method with the intention to scaffold and discover, the difference in achievement existed between these two groups could have been the result of ineffective implementation of group structure and its dynamics under exploration phase.

The effect of gender on students' achievement in science

A main effect was found for gender and it accounted for approximately 66% of the variance in the posttest scores. A sub-analysis revealed statistically significant differences between male and female students' achievement in science. The mean score for male students was higher than the mean score for females after being taught using guided discovery and regular 5E methods. This finding contradicts earlier studies on influence of gender on science achievement. These findings revealed that gender had no significant effect on the performance of students taught using guided discovery method [8, 9, 10]. However, the study of Third International Mathematics and Science Study (TIMSS) favoured this finding.

The effect of achiever groups on students' achievement in science

The findings showed that the effect of achiever grouping was statistically significant. All the three groups- low-medium-high achievers in the experimental group showed gains in the learning achievement. However, the statistical difference existed among these three groups revealed that high performing students benefitted to a greater extent when taught with guided discovery method compared with the medium and low achievers. These findings tally with those studies comparing the achievement of students in different tracks [6], which generally found ability grouping had more positive effects for high achievers and less positive effect for low achievers.

VI. CONCLUSION AND RECOMMENDATIONS

The findings appeared in the preceding sections indicated the need for an improvisation of the method presently used in the secondary classes for teaching science. The 5E learning cycle is an inquiry-based teaching modality implemented through the reforms in 2006 in the secondary classes intended to integrate content and process of science. The major purpose of the 5E cycle is to encourage students for the creation of knowledge through active participation in the learning process in a collaborative learning environment. Whatsoever the purposes of the implementation of 5E method, the difference that existed in the present study between the posttest mean scores of students taught with guided discovery and 5E method indicated the ineffectiveness of the latter method in improving students' performance. This means that the regular 5E method had an insignificant effect on students' achievement in science. This does not mean that the method itself is ineffective rather the way it is implemented in the class would be an issue. This is evident island wide in the persistent poor performance of secondary level students in science subject [17,18,19]. Therefore, it is recommended that the science teachers should use 5E learning cycle by incorporating inquiry-based instructional practices in order to engage students for critical thinking and understanding rather than disseminating knowledge. In addition, teachers should undergo in-service training to upgrade their knowledge on proper implementation of 5E learning instructional method as majority of the teachers are not acquainted with the practice of such innovative method.

The implication of the finding is that the gender difference in science achievement was statistically significant for both teaching methods. However guided discovery method produced the highest mean gain scores for male students. This finding is very much similar to the international trend where gender differences in science achievement favouring males [20]. Previous studies showed that at lower level, girls average performance were better than boys and had smaller score variation. At upper level boys outperformed girls and had larger variation. Thus, gender difference in achievement may not be the problem for science teachers; however, the girls who were lagged behind should be paid extra attention to enable them to reach the zone of proximal development and to scaffold.

With regard to the achievement among different ability groups, the finding showed that the higher the scorers the better the performance when taught with guided discovery method. This means that guided discovery method benefitted more the students who scored high in enhancing their performance. Thus, it can be concluded that improved achievement of students is influenced by the ability groupings besides the effect of teaching methods used in this study. Therefore, it is recommended that science teachers should pay attention to the different ability levels of students when using guided discovery method.

Teacher personality might have an effect on the differences between the achievement levels of students in the experimental and the control groups as these two groups were taught by different teachers. Teaching was remained to be parallel in both groups in order to line with the time tables of these classes. There was no alteration on the time allocated to science subject in each class. Therefore, regular science teacher was assigned to teach the control group using 5E method without disturbing the routine classes while the experimental group was taught using guided discovery method by the researcher.

However, to minimize the effect of teacher personality, the teacher who has taught the control group using the regular 5E method was well trained by the researcher on the aspects such as; teaching a lesson based on the lesson plan prepared by the researcher, communication skills, questioning techniques, which were found to be varied in two teaching learning situations.

REFERENCES

[1]   Curriculum development: Linking Science Education to Life. Report of a Sub-Regional Workshop UNESCO Regional Office for Education in Asia and the Pacific, 1981

[2]   Prince, M., and Felder, R. The Many Faces of Inductive Teaching and Learning. Journal of College Science Teaching, Vol.36,No.5.2007

[3]   Mayer, R. E. Learning and Instruction. 2nd Edition. Merrill Prentice Hall. 2008

[4]   Prince, M. Does Active Learning Work? A Review of the Research. *Journal of Engineering Education, 93*(3), 223-231. 2004. http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/Prince_AL.pdf

[5]   Ibe, H.N. Effects of Guided-inquiry and Expository Teaching Methods on Senior Secondary School Students' Performances in Biology in Imo State. Journal of Education Research and Behavioural Sciences. Vol.294), pp. 51-57.2013

[6]   Nbina, J. B, The Relative Effectiveness of Guided Discovery and Demonstration Teaching Methods on Achievement of Chemistry Students of Different levels of Scientific Literacy. Journal of Research in Education and Society; Volume 4, Number 1, April 2013

[7]   Mirasi, W., Osodo, J., and Kibirige, IComparing Guided Discovery and Exposition-with-Interaction Methods In Teaching Biology in Secondary Schools Mediterranean Journal of Social SciencesVol 4 No 14. . 2013.

[8]   Abdisa, G., Getinet, T. The Effect of Guided Discovery on Students' Physics Achievement. Latin American Journal of Physics Education. Vol.6, No.4. 2012

[9]   Akinbobola, A.O., and Afolabi, F. Constructivist Practices through Guided Discovery Approach: The Effect on Students' Cognitive Achievement in Nigerian Senior Secondary School Physics. Eurasian Journal of Physics and Chemistry Education, 2(1):16-25.2010

[10]   Udo, M. Effect of Guided-Discovery, Student-Centered Demonstration and the Expository Instructional Strategies on Students' Performance in Chemistry. African Research Review. An International Multi-Disciplinary Journal, Ethiopia, Vol. 4(4).2010.

[11]   Oloyede, O.I. Comparative Effect of the Guided Discovery and Concept Mapping Teaching Strategies on SSS Students' Chemistry Achievement. Humanity & Social Sciences journal, 5(1): 01-06. 2010.

[12]   Springer, L., Stanne, M.E., and Donovan, S.. Effects of Small Group Learning on Undergraduates in Science, mathematics and engineering and Technology: A Meta-Analysis," Review of Educational Research, Vol. 69, No. 1, pp. 21-52. 1999http://www.wcer.wisc.edu/archive/nise/publications/research_monographs/springer/springerall.pdf

[13]   Elvan, A. "Effectiveness of 5E Learning Cycle Model on Students' Understanding of Acid-Base Concepts". A published thesis submitted to the Graduate school of Natural and Applied Sciences of Middle East Technical University. 2005

[14]   Ajaja, P.O., and Eravwoke, U.O. Effects of 5E Learning Cycle on Students' Achiev ement in Biology and Chemistry. http://www.world-education-center.org/in.../downloadSuppFile/7.3.9/16

[15]   Samarasekara, N.G.P and. Vitharana, P.R.K.A. "Experiences and Challenges of Teaching Science at Junior Secondary Level".In Proceedings of the Abstracts of Jaffna University International Research Conference (JUICE- 2012).

[16]   Okada, T., and Simon, H.A. Collaborative Discovery in a Scientific Domain. http://onlinelibrary.wiley.com/doi/10.12...s15516709cog2102_1/abstrac. 1997.

[17]   National Assessment of Achievement of Grades 8 & 10 Students in Sri Lanka. Patterns and Trends in Performance. Summary Report of National Education Research and Evaluation Centre April, 2007

[18]   National Assessment of Achievement of Grade 8 Students in Sri
        Lanka. Summary Report of National Education Research and
        Evaluation Centre. 2012.

[19]   National Symposium on Reviewing of the Performances of School
        Candidates. Research and Development Branch, National Evaluation
        and Testing Service, Department of Examinations.2011

[20]   Gender Differences in Achievement. International
        Association for the Evaluation of Educational Achievement's Third
        International Mathematics and Science Study (TIMSS). July, 2000.