

Gender Fair Efficacy of Concept Mapping Tests in Identifying Students' Difficulties in High School Organic Chemistry

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Chemistry holds rich volume of abstract concepts, which requires substantial time and effort commitments from the students. There is an accumulative influence of growing knowledge in chemistry on social and economic life. A poor chemistry foundation at the secondary school will threaten any future effort to boost achievement not only in this subject, but individual development in general. The study of chemistry at the secondary school level aids students in developing elementary skills, knowledge and competence essential for problem solving in their setting. Chemistry contributes generating to the attainment of the aims of education and specifically helps individuals to develop effective process skills, critical thinking and competences required for dealing with observation, classification, measurement, counting numbers, recording, communication, prediction, hypothesis, inference, experimentation, interpretation of data, research, controlling variable and generalization (Ohodo, 2005). Relevance of chemistry for achieving these larger goals of schooling, and hence the need for devising tests that assess achievement in this and other school subjects in objective, reliable, and fair manner could never be overstated while discussing learning environment for excellence in education.

School setting is one of the factors that influence the academic success of adolescents. In classroom with both boys and girls are getting similar school setting for the learning endeavor. But the way by which both gender are listening to teachers' orders, doing a learning activity, acquiring information, attending evaluation may differ. The secondary school students, both boys and girls alike face several problems in conceptual understanding of novel chemistry topics. Gender bias in science classrooms has been, and still continues to be a problem, in learning and evaluation (American Association of University Women, 1999), despite improvements in the past two decades. Literature suggests that girls are still less likely than boys to take chemistry and higher-level mathematics and science courses in high school. By higher secondary level, chemistry is the least liked science subject among both boys and girls (Gafoor, 2011).

Effectiveness of any learning is evidenced through assessment in learning and of learning, using the extant practices. Assessment practices are accepted as one important aspect of learning environment. The nature of assessment and the specific technique and formats to a large extent determines the observed effectiveness of learning. Conventional test formats may not adequately investigate the whole aspects of learning. So the use of innovative gender fair assessment techniques may helpful in achievement and further learning of both boy and girl students. A fair test is one that is comparably valid for all groups and individuals and affords all examinees an equal opportunity to demonstrate the skills and knowledge which they have acquired and which are relevant to tests purposes (Roever, 2005). The concept-map, developed by Novak and Gowin, depict verbal, conceptual, or declarative knowledge in succinct visual or graphic forms (Quinn, Mintzes, & Laws, 2003, p. 12). It can arouse interest and motivation hence dissipates the anxious mind set of students and permits testing of higher order cognitive skills like application, analysis and synthesis. This study hence examines concept mapping as a gender fair test to appraise student achievement in organic chemistry unit for high schools.

Gender factor in chemistry achievement testing

The problem of students' persistent underachievement in chemistry is undoubtedly worrying. Several studies have revealed unimpressive academic achievement in chemistry at the secondary school level. Organic chemistry is highly conceptual and abstract in nature for a novice learner. When concepts in organic chemistry appear too difficult and students achieve poorly, one may be forced to conclude that during examinations students do not remember the facts or concepts learnt. Achievement test results over the years have shown an ever increasing gap between the performances of boys and girls in chemistry at senior secondary school level (Onekutu, 2002). Research till day demonstrate that exactly how gender affects science learning, especially chemistry learning, is less than clear. Male students have higher mean science achievement in earth science and physical science since 4th grade. Gender differences increase from 4th-grade to 12th-grade particularly in the physical sciences (Caillot,)

Achievement differences in schools are usually accounted by learner factors like motivational factors, instructional factors and assessment factors. Research studies conducted at the secondary school level indicate that there exists a gender difference in science self-efficacy (Debacker & Nelson, 2000). Extant constructivist approaches that influence classroom environment will help cognitive development in both male and female students to reduce gender differences in their academic achievement in all areas including science subjects (Dhindsa & Emran 2011). There was no gender effect or interaction between gender and method of instruction on critical thinking skills, science achievement, or attitude toward science (Sidney, 1989).

Though gender as a factor in science achievement has generated a lot of concern for science educators and researchers, results were somewhat inconclusive. In early school years there is no difference in the achievement of boys and girls and in secondary school year's boys perform better than the girls (Williams & Jacobson, 1990). Many researches revealed that boys achieved better than girls in sciences (Madu 2004, Iweka 2006, Obiekwe 2008, Agomaoh 2010, Ukozor 2011) in general, but secondary school boys had a more positive attitude toward chemistry, in particular, than girls (Harvey & Stables, 1986). In Australia too, males found chemistry more interesting than females (Barnes et al. (2005). According to National Centre for Education Statistics (2004) and Organization for Economic Cooperation and Development (OECD) (2004) too, boys generally outperform girls in science achievement. In United States boys are doing better than girls in problem solving and no gender differences in conceptual understanding (Longo, Anderson & Wicht, 2002). However, boys' advantage over girls in chemistry is not globally true. Steinkamp and Maehr (1984) conducted a meta-analysis of research on school science reported between the years of 1965 and 1981 and concluded that girls' attitudes toward chemistry are more positive than boys'.

Researches especially from third world countries too indicate that school science performance that in chemistry in special is better for girls than boys. For instance many studies from Nigeria revealed that female students achieve better than male students in science (Ocho, 1997). Ezeudu (1995) observed that sex has significant effect in favour of females in cognitive achievement. The results of some studies indicated that male students achieve significantly better than girls (Kador, 2001; Usman and Ubah, 2007). Whereas some other studies revealed no significant difference in the achievement of the two genders (Loofa, 2001). In Asian countries like Thailand and Brunei, girls compared to boys are doing better academically (Klainin, Fensham, & West, 1989; Fraser-Abder, 1990; Chung, Riah, & Dhindsa, 2001). Males generally were not enthusiastic about school chemistry, in Israel too

(Menis, 1983; Larson, 1996). This shows that researches so far has not arrived at consensus regarding exactly how gender and test-formats impacts measures of science achievement. In India too, student's preference for chemistry differs significantly with gender, with girls being better on it at the end of schooling (Gafoor & Shilna, 2013). As many researches reveal that the gender acts as a factor in learning, the gender gap in academic achievement is a significant path to explore.

Concerns about academic performance with respect to males and females have generated a considerable interest in the field of educational testing over the years. Apart from the subject interaction with gender in effecting student learning outcomes, the formats of tests that are employed too are found to influence, how students perform. According to Kimball (1989) boys respond well to novel situations than do girls. Other explanations are also put forward to gender difference in test outcomes, including confidence, anxiety and type of response required. Females do not perform well in science because of their low level of confidence and not their ability level (Clark & Gorski, 2002). Others too, report a strong positive female gender effect for written questions (Du Plessis, & du Plessis, 2009). Anxiety level of males was marginally lower than that of the female students, males scored higher than the females in the confidence learning scale supporting evidence that "males tend to be more confident than females" (Shiaki, 2005). When multiple-choice tests compared to essay-type tests, males have performed better than females (Harding, 1980; Murphy, 1982).

The use of concept map as an assessment tool dissipates the anxious mind set of students as they perceive it as an activity. Concept map permits higher order cognitive skills like application, analysis, and synthesis to be incorporated in testing. Comparing with the conventional test formats like multiple choice and true/false items, concept map arouse interest and motivation towards the learning-assessing practice. Here in this study the concept-mapping technique is used as an assessment tool along with the traditional measures of assessment like true/false items and multiple-choice items. Interaction of concept map with gender is studied as a teaching-learning technique, but not as a testing device. According to Ezeudu (2013), concept map as a strategy has no interaction with gender but the interaction of lecture method with gender was more effective on females than on males. Since, interaction effect of gender and grade was not examined, the purpose of the present investigation is to examine the effect of gender on assessment using concept map along with true/false and multiple choice items.

Objectives

This study is to examine whether gender difference exists in achievement in organic chemistry independent of the test-formats and if not, to identify which among the three test-formats viz., Concept-maps, true/false, and MCT formats are able to derive gender-fair measure of the achievement. In particular, this study focus is in examining efficacy of concept mapping as a gender fair test to appraise student achievement in organic chemistry unit for high schools.

Method

Sample

This study incorporates 117 standard IX students including 50 boys and 67 girls, from a rural government secondary school in Kerala.

Procedure

Twelve parallel items from 9th standard organic chemistry unit in the three formats namely concept-mapping (1), true or false items (2), and multiple-choice items (3) were constructed. A counter balanced design is used to eliminate the effect of sequence of administration of three types of tests. Students were divided into six groups in this design. Each group received different order of administration of three types of tests, viz., X₁X₂X₃, X₁X₃X₂, X₂X₃X₁, X₂X₁X₃, X₃X₁X₂, and, X₃X₂X₁. Thus, 76 each student responded to concept map and MCT format tests as the criterion test, while 82 students responded to T/F format test.

Results

In order for testing the efficacy of concept mapping as a gender fair test to appraise student achievement in organic chemistry, the main effect of gender, main effect of test –format and interaction-effect of gender and test-format, on achievement in school organic chemistry is studied using 2x3 Analysis of variance. Result obtained is presented in table 1.

Table 1

2x3 Analysis of Variance of Students' Achievement in School Organic Chemistry by Gender and Test-Format

Source	Type III Sum Of Squares	Df	Mean Square	F	Partial Eta Squared
Intercept	10111.84	1	10111.84	2416.37	.914
Gender	6.37	1	6.37	1.52	.007
Test	134.44	2	67.22	16.06**	.124
Gender *	25.65	2	12.82	3.06*	.026
Error	954.17	228	4.19		
Total	11586.00	234			

* $p < .05$, ** $p < .01$

Table 1 shows the results of the analysis conducted to find out if test format and the gender affect the achievement in organic chemistry. The results reveal interaction between gender and test format, $F(2,228) = 3.06$, $p < .05$, i.e., effect of test-format on achievement is modified (qualified) by gender. A detailed discussion of the effect of test format on achievement, and its modification by gender follows.

There is no gender effect on achievement in chemistry

The means and SDs of achievement scores obtained by girls and boys are in Table 2.

Table 2

Indices of Achievement in School Organic Chemistry by Gender

Gender	Mean	SD	N
Boys	6.52	2.29	100
Girls	6.82	2.09	134

There is no gender effect on achievement independent of the test format, [$F(1,232) = 1.52$, $p > .05$] (Table 1). Achievement for boys ($M = 6.52$, $SD = 2.29$) and girls ($M = 6.82$, $SD = 2.09$) in organic chemistry are not different if scores from all the three formats of tests are averaged (Table 2). This finding is in tune with that of previous researches (Loofa, 2001) that chemistry achievement needs not be different by gender.

Test format has effect on achievement scores

The means and SDs of achievement scores obtained when three select formats of testing was employed to measure student achievement in school organic chemistry is in Table 3.

Table 3

Students' Achievement in School Organic Chemistry by Test-Format

Test-Format	Mean	SD	N
Concept-Map	7.18	2.09	76
True/False	7.20	1.51	82
Multiple Choice	5.66	2.51	76

F tests the effect of test format on achievement in organic chemistry (Table 1) shows that test format has effect on achievement [$F(2,231) = 16.06, p < .01$]. Post-hoc comparison of the means revealed that test using MCT items ($M = 5.66, SD = 2.51$) is harder to score than tests that use True/false ($M = 7.20, SD = 1.51$) ($t = -6.61, p > .05$) and Concept-map ($M = 7.18, SD = 2.09$) items ($t = -5.74, p > .05$). Score on Test with Concept-map items do not differ significantly from that on Test with true/false (Mean difference = .02) items ($t = 0.097, p > .05$). Partial Eta square (.124) revealed that nearly 12.4 per cent variation in student achievement is attributable to test format.

Effect of test format depends on gender

Mean scores of Achievement in organic chemistry at three levels of testing vary with respect to gender $F(2,228) = 3.06, p < .05$ (Table 1). As effect of test-format on achievement is modified by gender (Table 1), three separate one-way ANOVAs were performed on achievement scores derived by three test formats, to examine whether scores from each test differ significantly by gender (Table 4).

Table 4

Analyses of Variance of Achievement Scores in School Organic Chemistry from Three Tests-Formats by Gender

Test format		Sum of Squares	df	Mean Square	F
Concept-Map	Between Groups	0.19	1	0.19	0.04
	Within Groups	327.23	74	4.42	
	Total	327.42	75		
True/False	Between Groups	2.41	1	2.41	1.06
	Within Groups	182.47	80	2.28	
	Total	184.87	81		
Multiple Choice	Between Groups	28.69	1	28.69	4.78*
	Within Groups	444.42	74	6.01	
	Total	473.11	75		

* $p < .05$

Simple effects tests by one way-ANOVA showed that when concept map was the test format male and female students score equally [$F(1,74) = 0.04, p > .05$]. Likewise, when true/false was the test format, male and female students score equally [$F(1,80) = 1.06, p > .05$]. However, when MCT test was employed, there is significant difference between girls and boys in school chemistry scores [$F(1,74) = 4.78, p < .05$]. The means and standard deviations of achievement scores for boys and girls while using the three test formats was studied further (Table 5).

Interaction between gender and test format brings about 2.6(Partial Eta square= .026) per cent variation in organic chemistry score in favour of girls.

Table 5

Cell Means of Students' Achievement in School Organic Chemistry by Gender by Test

Gender	Test	Mean	N	SD
Boys	Concept-Map	7.13	32	2.12
	True/False	7.39	36	1.52
	Multiple Choice Test	4.94	32	2.42
Girls	Concept-Map	7.23	44	2.09
	True/False	7.04	46	1.50
	Multiple Choice Test	6.18	44	2.47

The mean achievement scores in table 5 are plotted in figure 1 to reveal the interaction of test format with gender in deciding the achievement scores in organic chemistry.

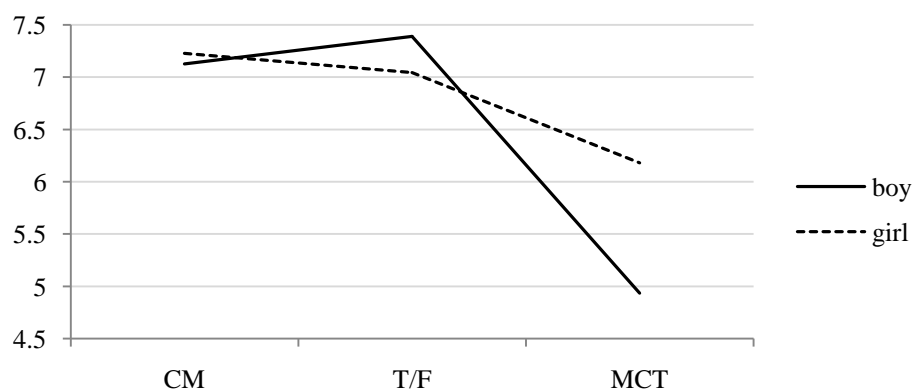


Figure 1. *Graphic display of the interactions between gender and test format on achievement in school organic chemistry*

While using multiple choice items, the mean score of Achievement in chemistry for boys (4.94) is less than that of girls (6.18)[$t=3.13$; $p<.01$]. However, with concept-map items, the mean score of Achievement in chemistry for boys (7.13) and girls (7.23) do not differ significantly [$t=-0.29$; $p>.05$]. With true/false items too, the mean score of Achievement in chemistry for boys (7.39) and girls (7.04) do not differ significantly [$t=1.48$; $p<.05$]. For tests with Concept–maps and true/false items, the mean achievement scores of boys and girls do not differ significantly, while with MCT tests, boys have relatively low mean score of Achievement in chemistry. Effect of test-format on achievement is modified (qualified) by gender.

Significant Gender difference in chemistry achievement is displayed with MCT format tests with scores favouring girls ($M=6.18$, $SD=2.47$), compared to boys ($M=4.94$, $SD=2.42$) [$t=3.13$, $p<.01$]; though other two formats of tests, true/false and concept-maps favour both genders equally. Conventionally used multiple choice items are less fair to boys in comparison to the concept map tests and true/false tests. In other words, one explanation for the gender difference in attitudes and achievement in chemistry can be had from the tests that favour one gender than the other.

Conclusion

The assessment process has a worthy role in learners as it authenticates the effectiveness of the learning endeavor. It should be free from bias to substantiate the further learning in an adequate way. True/false items and multiple choice items are the conventional modes of assessment so the use of concept map as an assessment technique might alter the nature of the assessment process itself. This study found nearly 15 per cent variation in performance in organic chemistry as accountable to test format in favour of girls when multiple choice items are used. This findings, at least partially explains the advantage of girls over boys in chemistry scores, as multiple choice item test items are important element in the customary achievement tests in schools in Kerala. The same time, concept mapping is at par with the true-false item format, in assessing student difficulties in organic chemistry in a gender fair manner. The findings highlight the need for developing improved formative test formats that could be used in accordance with fairer and inclusive schooling practices. The result validates the use of concept map as an assessment technique in addition to the use as an instructional strategy.

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