Higher Order Thinking Skills Among Secondary School Students in Science Learning

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ABSTRACT

A central goal of science education is to help students to develop their higher order thinking skills to enable them to face the challenges of daily life. Enhancing students' higher order thinking skills is the main goal of the Kurdish Science Curriculum in the Iraqi-Kurdistan region. This study aimed at assessing 7th grade students' higher order thinking skills level. The higher order thinking level test (HOTLT) was developed based on the Bloom Taxonomy of cognitive domain and consisted of 20 multiple-choice questions. The test was distributed to a randomly chosen sample comprising 418 7th grade students in the Iraqi-Kurdistan region. The overall findings revealed that the majority of the 7th grade students were at lower level of thinking skills (LOTL) n = 278 (79.7%). More male students were at lower level than female students. However, there was no significant difference between students' level of higher order thinking skills and their gender ($p > 0.05$). Based on the results of students' level of higher order thinking skills, the study provided evidence that almost all students needs to improve their higher order thinking skills especially the synthesis and evaluation skills required for improving students' creativity in science.

Keywords: *Cognitive skills, higher order thinking skills, secondary school students, higher order thinking level test.*

INTRODUCTION

Science consists of two components, scientific knowledge and the acquisition of scientific knowledge (Ozgelen, 2012). Facts, laws, hypotheses, and theories contribute to such scientific knowledge. Acquisition of scientific knowledge is represented by applying knowledge to another situation through using problem solving skills and various science process skills that encourage students to use their higher order thinking skills in science learning (Krau, 2011; Miri & Uri, 2007; Nuthall, 1999; Pappas, Pierrakos, & Nagel, 2012; Yao, 2012; Zohar & Dori, 2003). A central goal of science education is to help students develop their higher order thinking skills to enable them to face the challenges of daily life, through adopting activities that encourage students to use higher order thinking skills such as critical, reasoning, reflective and science process skills (Aktamis & Yenice, 2010; Davidson & Worsham, 1992; Zachariades, Christou, & Pitta-Pantazi, 2013). However, teachers often believe that this important goal is not intended for all students (Zohar & Vaaknin, 2001). The common belief among teachers is that tasks requiring HOT are appropriate only for high achieving students, whereas low achieving students, who can barely master the basic facts, are regarded as unable to deal with such tasks (Zohar, 1999).

Research on cognitive skills indicated that facilitating students' higher order thinking skills in the learning process helps to make them more aware of their own thinking and also fosters their learning performance and cognitive growth (Donald, 2002; Perkins, Jay, & Tishman, 1993). In addition, these HOT skills are activated when students encounter unfamiliar problems, uncertainties, questions, or dilemmas. Successful application of these skills in the science classroom result in explanations, decisions, performances, and products that are valid within the context of available knowledge and experience and that promote continued growth in these and other intellectual skills. Furthermore, these skills require students to transfer the scientific knowledge and apply it to new situations (Gillies, Nichols, Burgh, & Haynes, 2014).

Cultivating the student's ability to think at a higher level has been an important theme for redesigning and reforming learning systems (Kim, 2005). Therefore, in 2009 the educational system in the Iraqi-Kurdistan region has been reformed in general and the science curriculum has been revamped in particular. The new science curriculum has focused largely on promoting students' higher order thinking skills (HOTS), through doing different activities that require them to use these skills (Vernez & Constant, 2014). Besides, as Iraq is not involved in any international assessment program such as International Association for the Evaluation of Educational Achievement (IEA) and Programme for International Student Assessment (PISA), it is necessary to assess the students' performance in these skills to provide empirically grounded information on how far the new science curriculum has achieved its objectives, which will then inform policy decisions. Therefore, this study aimed at assessing the level of HOT skills among secondary school students in the Iraqi-Kurdistan region besides identifying any association between students' level of cognitive skills and their gender.

Bloom Taxonomy of Cognitive Domain

The concept of higher order thinking (HOT) is derived from the Bloom taxonomy of cognitive domain introduced in 1956 (Forehand, 2010). The cognitive domain involves knowledge and the development of intellectual skills (Bloom, 1956). This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve to develop intellectual abilities and skills. There are six major categories of cognitive processes, starting from the simplest to the most complex. Bloom categorized intellectual behavior into six levels of thinking: knowledge, comprehension, application, analysis, synthesis and evaluation (Clark, 2010; Yahya, Toukal, & Osman, 2012).

The categories in the Bloom taxonomy for cognitive development are hierarchically ordered from concrete to abstract (Pappas et al., 2012). The hierarchical progression identifies the lower level to higher level of cognitive processing (Clark, 2010); the first three levels of Bloom's taxonomy require basic recognition or recall such as knowledge, comprehension and application and these have been regarded as lower level of thinking skills. In contrast, the other three levels of Bloom's taxonomy require students to use higher order thinking skills hence fostering their learning performance (Forehand, 2010; Yahya et al., 2012). Based on research into the cognitive domain among secondary school students, the first three categories of the Bloom taxonomy, knowledge, comprehension and application measure the students' lower level of thinking skills (LOTS), whereas the other three levels of analysis, synthesis and evaluation measure the higher levels of thinking skills or HOTS (Chang & Mao, 1999; Pappas et al., 2012; Yahya et al., 2012). Under the revised Bloom's taxonomy the three higher levels are analyzing, evaluating and creating (Clark, 2010).

Objective of the Study

The overall aim of the study this study was to assess the level of higher order thinking skills among students in science learning as well as to identify if there is any association between students' level of cognitive skills and their gender. In order to achieve this objective two research questions were formed:

1. What is the current level of higher order thinking skills (HOTS) among 7th grade students in the Kurdistan region?
2. Is there any association between students' gender and their higher level of higher order thinking skills in science learning?

METHOD

STUDY SAMPLE AND SETTING

The participants of this study were grade seven (secondary) school students from public schools in the Iraqi-Kurdistan region. Using Raosoft sample size calculator software available from the website http://www.raosoft.com/samplesize.html the estimated sample size was 371 out of 10341 7th grade students in Duhok city in the Iraqi-Kurdistan region for the academic year 2013/2014. However, this is the minimum sample required for the study (Krejcie & Morgan, 1970). In order to minimize erroneous results and increase the study reliability, the target sample size was increased to 418 7th grade students in six secondary schools (three boys' and three girls' schools) in Duhok city. However, these schools were selected randomly and two classes for 7th grade were selected randomly from each of these schools. Some 69-70 students in the age range 13-14 years (first year attending 7th grade) were selected in each secondary school in Duhok city.

Instrument

In order to assess 7th grade students' level of thinking skills, the higher order thinking level test (HOTLT) was developed based on the Bloom Taxonomy of cognitive domain. According to previous research (Pappas et al., 2012; Scott, 2003; Yahya et al., 2012; Zohar & Dori, 2003) the first three levels of Bloom's taxonomy; knowledge, comprehension and application measures students' lower order thinking skills (LOTS), whereas the upper three levels of Bloom taxonomy which are, analysis, synthesis and evaluation measures students' higher order thinking skills (HOTS).

After reviewing tests of thinking skills (Facione, 1991; Leppa, 1997; Miri et al., 2007; Zohar, 2004), the researcher constructed a total of 25 items test in the form of multiple choice questions, which have been used widely in previous studies to assess students' cognitive skills. Therefore, in order to assess students' lower order thinking skills (LOTS), overall 13 questions distributed on the first three constructs of Bloom's taxonomy; knowledge, comprehension and application. While 12 questions were constructed to measure students' higher order thinking skills (HOTS) based on the last three constructs of Bloom's taxonomy for cognitive domain. To determine the total score of a student in HOTLT, the researcher used the scoring system for items in the form of multiple choices, in which one point is scored for the correct answer and zero score to the wrong answer or left unanswered or marked more than one answer. Thus, the total scores for the lower order thinking skills (LOTS) level is the summation of the scores for all questions in three constructs which is from 0-13 and the total scores for the higher order thinking skills (HOTS) level is from 0-12 points.

Pilot Study

To verify the clarity of instructions and test items, and to measure the time for completion, the test was translated into the Kurdish language and given to a group of 7th grade students representing the whole sample. The test was applied to an exploratory sample of 110 students in the Iraqi Kurdistan region; the students were given enough time to complete the test. The test reliability was determined using Kuder Richardson 20 formula; with a score of 0.806 the test was found to be highly reliable (Andrich, 1982). In order to identify the validity of the HOTLT, the test was reviewed by nine experts in science teaching method, measurement and evaluation and educational psychology. The content validity ratio (CVR) was employed. The CVR was developed in 1975 by Lawshe who provided a table of critical values for the content validity ratio. According to Lawshe's table, the critical value in case of 9 arbitrators starts from .78 (Lawshe, 1975). Therefore, the items not reaching the critical value were modified based on experts' feedback.

Procedure

The data collection was done by self-administration of the final version of the HOTLT after getting the ethical approval from the Ministry of Education in Duhok city in order to conduct a study in six secondary schools in Duhok city. The test was distributed among 418 7th grade students as the data from each school were collected in one day. Prior to test administration, all participants were informed about the purposes of the study. In this study, descriptive statistics were used to assess the student's level of cognitive development and chi square test was used to identify the association between students' level of higher order thinking skills and their gender using SPSS Version 21.

RESULTS

The study instrument was distributed among 418 7th grade students in the Iraqi Kurdistan region; some 69 incomplete responses were excluded from analysis. Therefore, 349 completed test sheets were received (83.4% response rate). Data normality was assessed through identifying the value of the skewness and kurtosis. According to Hair et al. (2010) the distribution of the data is considered normal if the empirical *z* -value lies between ±2.58 at (0.01 significance level); or ±1.96, at (0.05 significance level). On the other hand, the recommended range of skewness and kurtosis values is between ±1. As displayed in Table 1 the values for skewness and kurtosis lie within the range ±1. However, in order to assess students' levels of cognitive skills based on the six constructs of taxonomy for cognitive domain as well as to identify their level of thinking skills whether they are in higher or lower level, descriptive statistics was used as in Table1 and Table 2 respectively.

According to previous research on HOT, the first three constructs (knowledge, comprehension and application) refer to lower order thinking level (LOTL), while the last three constructs (analysis, synthesis and evaluation) refer to higher order thinking level (HOTL) (Forehand, 2010; Yahya et al., 2012). Therefore, the researcher computed the items for the first three constructs, 13 items as a lower order thinking level (LOTL) and the last three constructs which are 12 items as a higher order thinking level (HOTL), by using descriptive statistic as shown in Table 2.

Table 1: Students' Results on Cognitive Domain Constructs

Construct	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Mean	2.01	1.98	1.27	1.15	1.11	1.32
Std. Deviation	1.188	1.141	.929	.732	.880	.826
Range	5	4	4	4	4	4
Skewness	.159	-.037	.463	-.106	.465	.171
Kurtosis	-.410	-.652	-.109	-.846	.373	.098
Median	2.00	2.00	1.00	1.00	1.00	1.00

Table 2: Results of Student's Level of Thinking Skills in Science Learning

Level	N	Minimum	Maximum	Mean	Std. Deviation
LOT	349	1.00	11.00	5.25	2.076
HOT	349	0.00	7.00	3.58	1.636

LOT; Lower Order thinking, HOT; Higher Order Thinking

The students' results for higher order thinking level test based on the Bloom taxonomy indicated that the scores for all the constructs were very low; the highest mean was for knowledge construct with a score of 2.01 out of the maximum 5, followed by comprehension (1.98) and application (1.27), while the average mean score for synthesis was only 1.11 out of 4. The lowest mean (1.32) was recorded for evaluation construct. Regarding the students' level of thinking skills as in Table 2, the results indicated that the majority of the 7th grade students were in the lower level of thinking skills with a score of 5.25 out of 13 with minimum 1 and maximum 11 points. While, the score of higher order thinking level was 3.58 out of 12 with a maximum 7 points and the minimum point of zero. In order to identify the relationship between the students' level of higher order thinking skills and their gender, chi-square test was used as in Table 3.

Table 3: Association between Students' Level of Thinking Skills and Gender

Gender	Level of thinking skills		Total
	Lower (%)	Higher (%)	(%)
Female	142 (75.9)	45 (24.1)	187
Male	136 (84.0)	26 (16.0)	162
Total	278 (79.7)	71 (20.3)	349

Chi-square test. X^2 *=3.441, df. = 1, p = .064.*

Based on Table 3 data from 349 indicated that 278 (79.7%) of the students were in lower level of thinking skills, while only 71 (20.3%) of the students were in the higher level of thinking skills. Regarding the gender, the total number of female students was 187 with 142 (75.9%) in LOTL and 45 (24.1%) in HOT. Some 162 male students were included in this study; the majority of the male students (278 or 79.7%) were also in the lower level of thinking skills. However, the findings in Table 3 indicated that there is no significant difference between levels of thinking skills according to gender (p-value > .05).

DISCUSSION

It has been well verified that higher order thinking skills are essential for effective learning and form the central goal of science education. In 2009 the educational system in the Kurdistan region was reformed to meet the challenges of the 21st century, whereby the new secondary school science curriculum has focused largely on prompting students' Higher Order Thinking. However, after this reform no studies had been carried out to assess students' HOT skills. Therefore, the main purpose of this study was to assess secondary school students' level of cognitive development besides identifying the association if any between students' cognitive skill level and their gender. However, the findings of this study indicated that most of the 7th grade students were in the lower level of thinking, especially in synthesis and evaluation constructs, which are the skills that improve students' creativity in science (Swift, Zielinski, & Poston, 1996; Zohar, 2013). The findings indicate a slight difference between the levels of thinking skills linked to gender, as the number of male students in the lower level of thinking skills (LOTL) were higher than the number of the female students at the same level. However, the chi square test results show no significance difference between students' level of thinking skills with regard to gender (p > .05) which could be attributed to the fact that both male and female were learning in the same learning environment. These findings support previous research on cognitive skills (e.g., Aktamis & Yenice, 2010; Durmaz & Mutlu, 2012; Vernez et al., 2014).

Research suggests that the lower level of cognitive skills in science learning is caused by two main factors. First, the nature of the science curriculum that allows students the ability to fully understand how science as discipline function can help student to think in a higher level (Zawilinski, 2009). Second, the learning environment; in science education students should have the opportunity to begin thinking like scientists by engaging them in the process of thinking instead of merely ingesting the product of the scientists' disciplines (Bushman & Peacock, 2010; Gillies et al., 2014; Yao, 2012). Besides, in order to improve students' HOT in science, the teaching of science curriculum requires teachers to use appropriate teaching methods to engage student's active participation in the learning process (Bushman & Peacock, 2010; Gillies et al., 2014).

CONCLUSION AND IMPLICATION

Given the importance of cognitive skills for academic success, understanding the process of HOT skills as well as their assessment among students represents a central goal in science education. The results of this study contribute to the body of knowledge in assessing students' HOT skills in science learning as shown through assessment of HOT skills among 7th grade students in the Iraqi-Kurdistan region.

Findings of the study will benefit teachers and curriculum designers. First, Science teachers could benefit in assessing the students' cognitive skill level to identify weaknesses and improve them by adopting learning activities that encourage HOT skills. Second, curriculum designers could use the findings to assess how far the new science curriculum has achieved its objectives and devise solutions to enhance HOT among science students. HOT skills acquisition can also be enhanced through science teacher in-service professional development programs on how to use the curriculum to impart understanding of scientific concepts and their applications in daily life.

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