Effect of Gender on Students’ Scientific Reasoning Ability: A Case Study in Thailand

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Abstract

As scientific literacy is currently considered the central goal for development of the 21st century citizens, scientific reasoning ability is determined as an important factor for fostering student performance in science learning. Many science education researchers have reported that gender influenced students’ understanding and their attitudes toward science. However, there are not much investigation in the area of the interactions between gender and scientific reasoning ability. In order to gain more understanding on issue, this study aims to examine the effect of gender on students’ scientific reasoning ability in a context of Thailand. A total of 400 Grade 11 students from four co-educational schools in Northeastern region of Thailand participated in the study. The widely used and pre-validated Lawson Classroom Test of Scientific Reasoning (LCTSR) Lawson (2000) was administered to investigate students’ scientific reasoning ability in six constructs namely (i) Conservation of Mass and Volume (CMV), (ii) Proportional Thinking (PPT), (iii) Control of Variables (CV), (iv) Probabilistic Thinking (PBT), (v) Correlational Thinking (CT), and (vi) Hypothetical-deductive Reasoning (HDR). The results indicated that the gender does not significantly impact on students’ scientific reasoning ability for each construct. In addition, the lowest mean score for the students’ scientific reasoning ability were HDR, CV, PPT, respectively, for both genders. The finding of this indicated that there is critical area for improvement of students’ scientific reasoning ability. This also implied that instructional pedagogy in science classroom should be more emphasized on the way of teaching that (i) how to reason casually based on hypothesis generation (ii) how to design well fair science experiment, and (iii) how to determine correlation and conversation between target variables, in order to enhance the development of students’ scientific reasoning ability.

1. Introduction

Educational reform in the United States focus on the need for scientific literacy to prepare 21st century workforce (Bybee & Fuchs, 2006; Dani, 2009). Scientific literacy is currently considered as a central goal and critical learning outcome for science education standard in several countries(Bybee, 2008; Dahsah & Coll, 2007; Dani, 2009). In

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addition, Lawson (2009) referred to scientific literacy as an instructional goal, typically includes students’ understanding of the nature of science and scientific reasoning. Reasoning is the process of drawing conclusions from principles and evidence to new conclusions (Lee & She, 2010; Piraksa, Phaprom, Artdej, & Srisawasdi, 2011). Zimmerman (2005) argued that scientific reasoning includes the thinking skills involved in inquiry, experimentation, evidence evaluation, inference, and argumentation. Scientific reasoning consists of an overall pattern of reasoning typically includes the hypothetico-deductive and several sub-patterns, which can be characterized as formal operational schema such as combinatorial proportions and correlations (Lawson, 2004; Piajet, 1985). Lawson (2004) examined the reasoning patterns with the Hasler case study. The results showed that scientific inquiry and scientific reasoning as a process that seeks causes for puzzling observations as follows: 1) the identification of puzzling observations 2) the use of analogical reasoning to generate hypotheses typically include the specific predictions based on the hypothesis and its planned test 3) planned test are conducted and data are collected and analyzed. Also, Weld, Stier, and Birren (2011) reported that scientific reasoning as ability to define a science question, plan a way to answer the question, analyzes data, and interpret results.

In addition, Moore and Rubbo (2012) demonstrated that differences in student populations are important for comparison between normalized gains on concept inventories and the achievement on scientific reasoning. Lee and She (2010) investigated the Dual Situated Learning Model (DSLM) in order to develop students’ conceptual change and ability to reason scientifically. The results indicated that scientific reasoning plays an important role in the process of conceptual change. The results of their study were clear that the critical point is how to enable the instructional design to activate scientific reasoning which is required in teaching and learning science (Lee & She, 2010; Piraksa et al., 2011). Therefore, several educators indicated that relations between instructional methods and development of scientific reasoning ability have been broadly studied and have showed that inquiry-based classroom science instructions promote scientific reasoning ability (Bao et al., 2009; Lawson, 1994; Weld et al., 2011; Zimmerman, 2007). In other words, Johnson and Lawson (1998) found that the effect of reasoning ability and prior knowledge on biology in inquiry classes is higher than in expository classes. In addition, the integrative use of computer-based laboratory environments as part of science instructions (Friedler, Nachmias, & Linn, 1990; Gunhaart & Srisawasdi, 2012; Liao & She, 2009; She & Liao, 2009).

The current study aimed to find out answer to the question: Is there a gender difference with scientific reasoning ability?

2. Literature review

2.1. Gender difference

In relation to the gender difference, some educators indicated that no significant difference in the scientific reasoning between males and females (Al-Zoubi, El-shar’a, & Al-Salam, 2009; Dimitrov, 1999; Lappan, 2000; Valamides, 1996). Al-Zoubi et al. (2009) found that there was no significant difference in the ability of scientific reasoning with respect to gender based on Lawson’s test. Valamides (1996) investigated the substantial deficiencies in the students’ reasoning ability which was related to proportional reasoning items. The results showed that no difference was found, while others reported significant gender difference (Soyibo, 1999; Valanides, 1997; Yang, 2004; Young & Fraser, 1994). Spelke (2006) revealed that males and females showed somewhat different cognitive profiles. Marcia and Steven (1983) investigated the role of aptitudes and experiences in gender differences in scientific reasoning. The results showed that scientific reasoning task known to be solved by males more frequently than females. Yang (2004) reported that males were found to be better than females in constructing and using theories. Similarly, the study conducted by Valanides (1997) showed that males had significantly better performance than females on probabilistic reasoning.
3. Method

3.1. Research design

This research was conducted to explore the effect of gender on students’ scientific reasoning ability by using a survey research.

3.2. Study participants

The participants in this study were 400 Grade 11 students from four co-educational schools in Northeastern region of Thailand participated in the study. The study was administered to a group of 14 school students from 4 different schools size and study was carried out in the second semester of year 2011–2012. 400 grade 11 students from various school size, participated in the study; 200 students (58 males, 142 females) were from small school size, 65 students (30 males, 35 females) were from medium school size. 95 students (27 males, 68 females) were from large school size, and 40 students (12 males, 28 females) were from extra-large school size.

3.3. Instrument

The Lawson Classroom Test of Scientific Reasoning (LCTSR) (Lawson, 2000) was first developed in 1978 and revised in 2000. The LCTSR consists of 12 two tier questions and thus 24 items. Each question has a second tier question designed to measure student’s in-depth scientific understanding of the process. The concepts measured by the instruments were: Conservation of Mass and Volume (CMV) (items 1, 2, 3 and 4), Proportional Thinking (PPT) (items 5, 6, 7 and 8), Control of Variables (CV) (items 9, 10, 11, 12, 13 and 14), Probabilistic Thinking (PBT) (items 15, 16, 17 and 18), Correlational Thinking (CT) (items 19, 20), and Hypothetical-deductive Reasoning (HDR) (items 21, 22, 23 and 24). The instrument had been established validity and reliability. For example, Lawson, Banks, and Logvin (2007) demonstrated a posttest cronbach’s $\alpha$ was 0.79. She and Lee (2008) demonstrated cronbach’s $\alpha$ was 0.71 for the pretest, 0.61 for the post-test, and 0.76 for the retention-test. Reliability of the test was found to be 0.71 by calculating internal consistency using Cronbach’s alpha which is considered reasonable for use in the study. Correct responses were awarded one point that be given for both correct answer.

3.4. Domain of scientific reasoning ability

Patterns of scientific reasoning as a domain of scientific reasoning ability includes (i) Conservation of Mass and Volume (CMV), (ii) Proportional Thinking (PPT), (iii) Control of Variables (CV), (iv) Probabilistic Thinking (PBT), (v) Correlational Thinking (CT), and (vi) Hypothetical-deductive Reasoning (HDR).

3.4.1. Conservation of Mass and Volume (CMV)

The Conservation of Mass and Volume as involves two objects of identical size, shape, and weight. Students are asked about the relative weights of the pieces when the objects weigh the same by placing them on opposite ends of a balance beam.

3.4.2. Proportional Thinking (PPT)

Proportional Thinking can be conceptualized in the following ways: identification of two extensive variables that are applicable to a problem that recognition of the rate of intensive variables whose constancy determines the linear function; and application of the given data and relationships to find an additional value for one extensive variable or comparison of two values of the intensive variable computed from the data as a comparison problem.

3.4.3. Control of Variable (CV)
Control of Variables is defined as the process which includes controlling the dependent and independent variables that affect the continuity of the situation while test in the hypothesis.

3.4.4. Probabilistic Thinking (PBT)

Probabilistic Thinking as a situation in which are interested in the fraction of the number of repetitions of a particular process that produces a particular result when repeated under identical circumstances a large number of times.

3.4.5. Correlational Thinking (CT)

Correlational Thinking as the thought patterns individuals use to determine the strength of mutual or reciprocal relationships between variables such as relationships allow for the making of predictions during scientific exploration.

3.4.6. Hypothetical-deductive Reasoning (HDR)

Hypothetical-deductive Reasoning as the characteristics of the reasoning process which yields developing and organizing possible solutions for dealing with a problem in any step and domain of life.

3.5. Data collection and analysis

For investigating students’ scientific reasoning ability, the LCTSR was administered to the students at the physics classroom. For analysis of students scientific reasoning ability significance of gender differences was analyzed using mean, standard deviation, and paired t-test for comparisons between gender scores.

4. Results and discussions

The comparison of students’ scientific reasoning ability scores using mean, standard deviation, and t-test independent discovered that students’ scores in scientific reasoning ability were no differences between males and females (p<.05). The paired t-test for students’ scientific reasoning ability are display in Table 1.

<table>
<thead>
<tr>
<th>Reasoning patterns</th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation of Mass and Volume (CMV)</td>
<td>Males</td>
<td>127</td>
<td>0.879</td>
<td>0.578</td>
<td>1.408</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>273</td>
<td>0.787</td>
<td>0.612</td>
<td></td>
</tr>
<tr>
<td>Proportional Thinking (PPT)</td>
<td>Males</td>
<td>127</td>
<td>0.459</td>
<td>0.554</td>
<td>0.751</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>273</td>
<td>0.509</td>
<td>0.631</td>
<td></td>
</tr>
<tr>
<td>Control of Variables (CV)</td>
<td>Males</td>
<td>127</td>
<td>0.465</td>
<td>0.386</td>
<td>0.595</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>273</td>
<td>0.488</td>
<td>0.360</td>
<td></td>
</tr>
<tr>
<td>Probabilistic Thinking (PBT)</td>
<td>Males</td>
<td>127</td>
<td>0.677</td>
<td>0.585</td>
<td>0.809</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>273</td>
<td>0.625</td>
<td>0.587</td>
<td></td>
</tr>
<tr>
<td>Correlational Thinking (CT)</td>
<td>Males</td>
<td>127</td>
<td>0.685</td>
<td>0.642</td>
<td>0.870</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>273</td>
<td>0.625</td>
<td>0.625</td>
<td></td>
</tr>
<tr>
<td>Hypothetical-deductive Reasoning (HDR)</td>
<td>Male</td>
<td>127</td>
<td>0.423</td>
<td>0.418</td>
<td>0.795</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>273</td>
<td>0.388</td>
<td>0.391</td>
<td></td>
</tr>
</tbody>
</table>

The results showed that there were no differences between genders. The evidence is consistent with research finding of Valamides (1996), Dimitrov (1999), and Al-Zoubi et al. (2009) that no differences were found among males and females in the scientific reasoning ability. However, descriptive scores for specific scientific reasoning patterns were generated as assessed by the LCTSR. Students within the observed population demonstrated significant difficulties with PPT, CV, and HDR. Our result confirm the findings of Moore and Rubbo (2012) that students had significant difficulties with CV, and HDR. Interestingly, scientific methods were necessary to develop both CV and HDR. The students in this study showed low performance on PPT which could attribute to poor
preparation in mathematics. Student’s difficulty with CV could be attributed to the fact that the teaching intervention were lacked of emphasis on laboratory.

5. Conclusions and implementations

A Scientific reasoning has significant instructional implications for enhancing students’ scientific reasoning ability (Zeineddin & Abd-El-Khalick, 2010). The results also revealed that there is no interaction between gender and ability to reason scientifically, that is the scientific reasoning ability effect does not depend on gender. This finding highlights the importance of the need for instructional design that is focused on supporting content knowledge might not suffice to promote scientific reasoning ability among students. Therefore, devising curricula that focus on promote students’ scientific reasoning, especially PPT, CV and HDR patterns. Moreover, it is suggested that science instructions should be taught by inquiry-based methods (Johnson & Lawson, 1998; Lawson, 1995; Weld et al., 2011; Zimmerman, 2007), computer-based laboratories (Friedler et al., 1990; Gunhaart & Srisawasdi, 2012; Liao & She, 2009; She & Liao, 2009) which foster students ‘scientific reasoning ability as the core of scientific literacy.

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References


