Enhancement of learning achievement and integrated science process skills using science inquiry learning activities of chemical reaction rates

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Abstract

High school students at Ramwittaya Rachamunklapisek School in Thailand in previous years had records of low learning achievement in chemistry, especially in the area of chemical reaction rates. They also had low levels of integrated science process skills due to lack of experience in inquiry activities. This study aimed to improve students’ achievement records and integrated science process skills through 12 hours of science inquiry activities. Sixty-three grade 11 students at the school participated in the study in second semester of 2011. The paired-sample t-test analysis showed that students’ post-achievement score (mean 26.13, SD 6.40) were statistically higher than their pre-achievement score (mean 8.75, SD 2.51) at p-value less than 0.001. They also obtained an average of 74.52% in integrated science process skills (good level). It was found that predict-observe-explain activities effectively engaged students in the first step and throughout the inquiry learning process. Science inquiry activities effectively enhanced students’ learning achievements and integrated science process skills.

Keywords: Science inquiry, chemical reaction rates, science process skills;

1. Introduction

Previously, the learning achievements in Chemistry of grade 11 students at Ramwittaya Rachamunklapisek School in Surin Province of Thailand had been lower than the school standard proposed at 2.50. Also, the students’ integrated science process skills were at a low level due to few opportunities to experience science inquiry experiments. One of the major topics in Chemistry for grade 11 students is chemical reaction rates. Many students complained that the topic was difficult as it involved many intangible concepts and required some calculation (Yasukham, Supasorn & Wongkhan, 2011). The goal of the school was to obtain an Ordinary National Educational Test (O-NET) score higher than that of Surin Province. O-NET of Thailand revealed that the Science subject score in Chemistry (Matters and Properties) for high school students at Ramwittaya Rachamunklapisek School from 2009 to 2010 had been lower than the average provincial and national scores, see Table 1 (NIETS, 2011). Science inquiry is one of the most popular approaches in science learning activities since it enhances students’ conceptual
understanding as well as their science process skills. Science inquiry activities related to chemical reaction rates were developed to solve the above situation.

### Table 1. Percentage of O-NET Scores for Chemistry (Matters and Properties) at Ramwittaya Rachamunklapisek School

<table>
<thead>
<tr>
<th>Level</th>
<th>2009 (Available score = 28)</th>
<th>2010 (Available score = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Ramwittaya Rachamunklapisek School</td>
<td>7.33</td>
<td>3.64</td>
</tr>
<tr>
<td>Surin Province</td>
<td>8.01</td>
<td>3.93</td>
</tr>
<tr>
<td>Thailand</td>
<td>8.60</td>
<td>4.35</td>
</tr>
</tbody>
</table>

### 2. Literature review

#### 2.1. Science inquiry in Chemistry

Science inquiry has been highly advocated to be implemented in middle and high school science since the last century. Some common constraints to implement inquiry in Chemistry include inadequate Chemistry knowledge and nature of science, lack of pedagogical skills, inadequate access to appropriate curriculum materials, and teachers teaching outside their fields of expertise (Roehrig & Luft, 2004). Science inquiry has been verified as an effective learning approach to enhance conceptual understanding and critical thinking skills for high school students in Thailand (Yasukham, Supasorn & Wongkhan, 2011). This approach allows students to take control of their experiments through the five essential features of science inquiry, 1) students sharpen, clarify questions provide by instructors or pose their own questions in the step of engaging to scientifically-oriented questions, 2) students determine what constitutes evidence and gather it or just give priority to provided evidence in the step of giving priority to evidence, 3) students formulate explanations after summarizing evidence in the step of formulating explanations, 4) students examine other resources and form the links to explanations in the step of connecting explanations to scientific knowledge, and 5) students form reasonable and logical arguments to communicate explanations in the step of communicating and justifying explanations (National Research Council, 2000). The implementation of corresponding predict-observe-explain (POE) activities at the engaging to scientifically-oriented questions enhances students’ motivation to find out an answer via a scientific process (Yasukham, Supasorn & Wongkhan, 2011). This direct participation in the scientific life can serve as an inducement to the future study of chemistry for many students (Green, Elliott & Cummins, 2004).

#### 2.2. Integrated science process skills

Science process skills can be categorized into two levels, basic and integrated. Integrated science process skills consist of five skills: 1) identifying and controlling variables, 2) defining operationally, 3) formulating hypotheses, 4) experimenting including being able to design their own experiment to test a hypothesis using procedures to obtain reliable data, and 5) interpreting data and drawing conclusions. It is advisable that teachers cannot expect big improvements in experimenting skills after practicing just a few experiments. Instead students need multiple chances to improve these skills in different contexts (Padilla, 1990).

Inquiry is one of the most effective teaching approaches to enhance students’ science process skills (Abdulhanung, Supasorn & Samphao, 2011). It should be implemented as often as practical. If students experience even a few inquiry activities each semester throughout their study in middle and high school, they become more self-confident, possess high skills in the science process and critical thinking, and unafraid of doing science (Deters, 2005). There is some concern that inquiry-based instruction is time-consuming, so the introduction of inquiry into the traditional Chemistry course takes more time and involves fewer topics, and the easiest action would be to implement inquiry instruction as supplements or demonstrations in the traditional class (Sanger, 2007).
3. Research methodology

3.1. Goals and objectives

The main goal of this study was to implement science inquiry activities related to chemical reaction rates to promote students’ conceptual understanding and integrated science process skills. More specifically, the objectives of this study were to investigate 1) students’ conceptual understanding of chemical reaction rates prior to and after experiencing science inquiry activities, and 2) students’ integrated science process skills after experiencing science inquiry activities.

3.2. Research tools

3.2.1. Science inquiry activities related to chemical reaction rates

Four science inquiry activities related to chemical reaction rates (12 hours) were developed. These included: 1) definition of reaction rates (2 hours), 2) determination of reaction rates (2 hours), 3) energy and reaction progress and collision theory (2 hours), and 4) factors influencing reaction rates (6 hours). Each activity was designed as a science inquiry that required students to participate in the five essential features of inquiry. In addition, a POE activity was implemented in the first inquiry feature to deeply engage students in scientific questioning. This encouraged them to find the answer for their engaged question through the inquiry process. The experiments were approved in terms of the five essential features of inquiry and their variations by six inquiry experts.

3.2.2. Data collecting tools

Data collecting tools in this study consisted of three main tools:

1. Achievement test of chemical reaction rates. The test consisted of 40 multiple-choice items, mainly higher order cognitive skill questions. The test items were selected from 60 items with item difficulty (p) index between 0.40 and 0.80, and discrimination index (r) between 0.27 and 0.64. The reliability of the test calculated by the Kuder-Richardson Formula 20 (KR-20) was 0.801.

2. Science process skills rubric system. The rubric was developed to evaluate students’ integrated science process skills from their plan prior to the activity and reports after the activity.

3.3. Implementation

The participants of this study were 63 grade 11 students, 34 students from Classroom I and 29 students from Classroom II. They were purposively sampled from the population of 136 grade 11 students from Classroom I to IV of grade 11 students in the Science-Mathematics Plan at Ramwitraya Rachamunklapisek School in the second semester of the 2011 academic year. The science inquiry activities related to chemical reaction rates were implemented for four weeks, three hours a week. Students were asked to participate in the following process: 1) complete a pre-achievement test related to chemical reaction rates, 2) perform science inquiry activities related to chemical reaction rates, in which they were required to submit a group science inquiry activity plan and report prior to and after finishing each activity, and 3) complete a post-achievement test related to chemical reaction rates (parallel to pre-test).

3.4. Data analysis

The collected data in this study included pre- and post- achievement test scores related to chemical reaction rates and integrated process skills. Paired-sample t-test analysis was performed to identify mean differences between the pre- and post-achievement test scores for this one group pretest and post-test study. The scores of students’ integrated science process skills were analyzed in terms of means and SDs. Percentages of mean scores in the ranges of 0-50, 51-60, 61-70, 71-80, and 81-100 were interpreted as very poor, poor, fair, good, and excellent respectively.
4. Results and Discussion

The study results were categorized into two aspects, achievement scores and integrated science process skills.

4.1 Students’ learning achievement scores related to chemical reaction rates

The paired-samples t-test analysis indicated that students obtained a post-achievement score (mean 26.13, SD 6.40) significantly higher than the pre-achievement score (mean 8.75, SD 2.51) related to chemical reaction rates at p-value less than 0.001 (Table 2). In addition, the post-achievement score for each topic was statistically higher than the pre-achievement score at p-value less than 0.001. The highest gains in content knowledge were in the topics of determination of reaction rates (51.60%) and definition of reaction rates (49.20%), while the lowest gains were in the topics of energy and reaction progress and collision theory (38.60%) and factors influencing reaction rates (41.60%). These results may have been due to the fact that there was just a model (no experiment) illustrating the energy and reaction progress and collision theory, so the students might not have been able to understand the concepts as well as the topics with corresponding experiments. In addition, there are many factors influencing reaction rates, such as temperature, catalyst, concentration, and nature and surface areas of reactants, so students may have become confused about influences of reaction rates when two or more factors were present in the reactions being considered.

Table 2. Pre- and post-achievement test scores related to chemical reaction rates

<table>
<thead>
<tr>
<th>Topics</th>
<th>Possible score</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Gain</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition of reaction rates</td>
<td>5</td>
<td>0.76</td>
<td>3.22</td>
<td>2.46</td>
<td>15.72</td>
</tr>
<tr>
<td>Determination of reaction rates</td>
<td>5</td>
<td>0.70</td>
<td>3.28</td>
<td>2.58</td>
<td>15.91</td>
</tr>
<tr>
<td>Energy and reaction progress and collision theory</td>
<td>5</td>
<td>1.46</td>
<td>3.39</td>
<td>1.93</td>
<td>11.55</td>
</tr>
<tr>
<td>Factors influencing reaction rates</td>
<td>25</td>
<td>5.82</td>
<td>16.22</td>
<td>10.40</td>
<td>17.76</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>8.75</td>
<td>26.13</td>
<td>17.38</td>
<td>22.22</td>
</tr>
</tbody>
</table>

4.2) Students’ integrated science process skills

The students’ science activity plans and reports were scored in terms of integrated science process skills by the use of the rubric developed by the authors. The study showed that the students achieved a good level (74.52%) in integrated science process skills. Students were identified as “excellent” at the skill of identifying and controlling variables and “good” at defining operationally (74.76%), formulating hypotheses (76.08%), and experimenting skills (74.65%). However, they were “fair” at the skill of interpreting data and drawing conclusion (74.52%). This may have been due to the fact that they had opportunities to practice the skills of identifying and controlling variables, defining operationally, formulating hypotheses, and experimenting skills, which were more emphasized by instructors during their middle and high school careers. However, they had only a few opportunities to practice the skill of interpreting data and drawing conclusion since many instructors often skipped this time-consuming step. As a result, the students’ skill of interpreting data and drawing conclusion was less developed.

Table 3. Students’ score of integrated science process skills

<table>
<thead>
<tr>
<th>Integrated science process skills</th>
<th>Available</th>
<th>Mean</th>
<th>SD</th>
<th>%</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identifying and controlling variables</td>
<td>15</td>
<td>12.33</td>
<td>2.43</td>
<td>82.22</td>
<td>Excellent</td>
</tr>
<tr>
<td>2. Defining operationally</td>
<td>10</td>
<td>7.48</td>
<td>1.61</td>
<td>74.76</td>
<td>Good</td>
</tr>
<tr>
<td>3. Formulating hypotheses</td>
<td>15</td>
<td>11.41</td>
<td>3.04</td>
<td>76.08</td>
<td>Good</td>
</tr>
<tr>
<td>4. Experimenting</td>
<td>35</td>
<td>26.13</td>
<td>6.40</td>
<td>74.65</td>
<td>Good</td>
</tr>
<tr>
<td>5. Interpreting data and drawing conclusion</td>
<td>25</td>
<td>17.17</td>
<td>2.72</td>
<td>68.70</td>
<td>Fair</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>74.52</td>
<td>9.64</td>
<td>74.52</td>
<td>Good</td>
</tr>
</tbody>
</table>
5. Conclusions and implications

The results of this study verified that science inquiry activities were effective to engage student in active learning (Zhao & Wardeska, 2011) and to enhance students’ learning achievement related to chemical reaction rates due to students’ post-achievement score being statistically higher than the pre-achievement score at \( p \)-value less than 0.001. This type of activities also promoted students’ to use their science process skills in each of the five essential features of science inquiry, so their integrated science process skills were enhanced. It confirmed that the science inquiry approach provides students with opportunities to practice how scientists really do science through the science inquiry process. In other words, students have a chance to sharpen, clarify or pose scientifically-oriented question, plan and conduct experiments to gather data regarding the question, formulate explanations from evidence to answer the question, connect explanations to scientific knowledge, and communicate and justify their explanations (National Research Council, 2000). This direct participation in the inquiry process can enhance their understanding and science process skills in future study of chemistry and other sciences (Green, Elliott & Cummins, 2004).

The results may have implied that the insertion of a POE activity in the first step of the science inquiry process promoted students’ motivation to answer their engaged question through the inquiry process (Yasukham, Supasorn & Wongkhan, 2011). It is advisable that continuous practice of inquiry experiments be used to enhance students’ integrated science process skills (Padilla, 1990).

The authors aim to further investigate how science inquiry affects student progression of higher-order thinking skills, such as critical thinking, and integrated science process skills when they have opportunities to practice a few science inquiry activities each semester throughout their high school careers.

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