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Contents

1. Factors Affecting Chemistry Achievement and Academic Performance among First Year Nursing Students..........................................................5
   Rizalina E. Andamo

   Richard Deanne C. Sagun and Maricar S. Prudente

3. Assessment on the Conceptual Learning in Elementary School Electrical Activities Via Manufacturing Scientific Toys ........................................39
   Jian Yi Lin and Ching-san Lai

4. An empowerment evaluation approach in shifting a South African science teacher towards an inquiry-based pedagogy ........................................58
   Umesh Ramnarain and Augustine Nceba Makhubalo
5. Relooking environmental science education: The pedagogical value of community-based research projects in higher education

Tai Chong Toh and Siok Kuan Tambyah

6. Promoting Self-Directed Learning (SDL) and Assessment as Learning (AaL) in Science Education in Hong Kong: A pilot study in a Hong Kong Secondary School

Michael Tsang and Tracy Cheung

7. Nurturing Scientific Literacy for All Undergraduates via Science Classics

Kiang Kai Ming, Cheung Hang Cheong Derek and Ng Ka Leung Andy

8. The Factors of Pre-service Teacher Training Process to Create Active Learning in Teaching Science: Case Study the Pre-service Science Teachers in Thailand

Ruhaisa Dearamae and Jiradawan Huntula

9. Nature of Science in Students’ Conceptions of Scientists: A pilot study of an “Act a Scientist -Test”

Jaakko Turkka, Maya Kaul and Maija Aksela

10. Generating Scientific Explanation: The Effects of Generate an Argument Instructional Model on Newton’s Laws of Motion Classroom

Saksit Hemkaew and Pannida Meela
11. Uniqueness of Senior High School Students’ Sequence Expressions of Triangle of Representation in Electrochemistry ......................................................... 174
Chontawat Meedee and Romklao Jantrasee

12. Assessment Literacy of Science Teachers Across Levels ............................. 191
Rizalina E. Andamo, Roselle Laureano and Marilyn U. Balagtas

13. Development of Game-based Science Simulation for Promoting Elementary School Students’ Learning in Plant Growth .................................................. 206
Daranee Jaimeetam and Niwat Srisawasdi

14. A Strong Daily Terminology Influence Biology Learning: Biological Classification as a Case Example ................................................................. 226
Thitaporn Inngam and Parichat Saenna

15. The study of students’ understanding in nature of science .......................... 246
Kamonlapat Puengpan, Kanyarat Cojorn, Kanyarat Sonsupap and Somsong Sitti

16. The study of students’ achievement motivation in Physics .......................... 259
Peeradon Onsee, Kanyarat Cojorn, Kanyarat Sonsupap and Somsong Sitti
Factors Affecting Chemistry Achievement and Academic Performance Among First Year Nursing Students

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Candidate, Doctor of Philosophy in Science Education, Philippine Normal University, Manila, Philippines
Abstract

Identifying factors affecting academic performance enhances retention rates, contributes to academic success, and ensures that students are better prepared in facing challenges in a dynamic and ever-expanding workplace. This descriptive normative survey study identified factors and investigated their effects on Chemistry achievement and academic performance among freshman nursing students. One hundred and five students, grouped according to their grade-point average (GPA) as high ability (HA), middle ability (MA) and low ability (LA), accomplished a questionnaire consisting of five sets of questions for variables academic competence (AC), test competence (TC), time management (TM), studying techniques (ST), and test anxiety (TA). Scores were tallied with one as the highest and five the lowest. Frequency, mean, standard deviation, Pearson Product-Moment Coefficient of Correlation, F-test, and non-stepwise multiple linear regression were utilized. Results revealed that the students had the same level of Chemistry achievement and GPA. In terms of academic performance, MA group was most homogeneous (M=2.37; SD=0.13) and LA group as most heterogeneous (M=3.37; SD=0.35). In terms of Chemistry achievement, the HA group was most intact (M=1.78, SD=0.32) and LA group as least intact (M=4.67; SD=0.76). The three ability groups had moderately positive overall performance score (OPS) but HA group had higher OPS than the lower groups. Correlations among the variables ranged from low to marked substantial, except between ST and CHEM and TA and ST with negligible correlation. The AC, TM and OPS were found to be the strongest predictors of Chemistry achievement and academic performance. Results suggest that incoming freshman students be admitted and grouped on the basis of their high school GPA to maximize learning and make it more effective. Programs on academic competence and time management will enable students to assess themselves and perform better. These could lead to the fulfillment of their common goal, to achieve academic success.
Factors Affecting Chemistry Achievement and Academic Performance Among First Year Nursing Students

Poor performance and failure are major concerns to educators who are interested in the 'whys' and 'hows' of learning. When students perform poorly, the school administrators, faculty and staff propose possible solutions or programs to remediate the problems by determining the factors that affect their performance. Our Lady of Fatima University (OLFU) is susceptible to issues on student performance.

Nursing is one of the many health-based courses offered by the Our Lady of Fatima University (OLFU), where the researcher was a faculty member. For the past twenty years, the school has produced topnotchers in the nursing board examinations and related fields such as pharmacy, medical technology and medicine. But as observed by the researcher, a big percentage of failure in different subjects among first year nursing students and passing grades are either average or below average.

Science subjects are part of all degree courses. One of the most fundamental science subjects in all degree courses is Chemistry. Medicine, nursing, dentistry, engineering, accounting, medical technology and many other diverse areas of study relate in a very essential way to Chemistry. In the nursing curriculum, Chemistry is an important foundational course. An aspiring nurse should be well informed of the different occurrences, functions, structures, reactions and the chemistry of the various biochemical systems and the biomolecules involved in it. An understanding of these will give him better appreciation of his roles in the maintenance of life and order in the human body.

Many studies that explored the different factors affecting student performance are focused on cognitive, behavioral, and environmental issues that surround the learner. Identifying factors affecting academic performance and success is a quest for most teachers and a primary goal of most educational researchers. This study was conducted to determine
the factors affecting Chemistry achievement and academic performance among first year nursing students of Our Lady of Fatima University and sought to answer the following problems:

1. What is the profile of the students in terms of the following variables?
   1.1 Chemistry Achievement (CHEM)
   1.2 Academic Performance (GPA)
   1.3 Academic Competence (AC)
   1.4 Test Competence (TC)
   1.5 Strategic Studying Techniques (ST)
   1.6 Time Management (TM)
   1.7 Test Anxiety (TA)
   1.8 Overall Performance Score (OPS)

2. Are there significant relationships among the Chemistry achievement, academic performance (GPA), and performance variables?

3. Which among the performance variables serve as best predictors of
   3.1 Chemistry achievement and
   3.2 academic performance (GPA)?

**Methods**

Descriptive normative survey type of research was used in this study. This method attempts to interpret the present status of a particular dependent variable for the purpose of obtaining a generalized knowledge for future use.

**Study Sample**

Random sampling technique was employed in selecting the student-respondents. From the list of 1,100 first year nursing students enrolled during the second semester of academic year 2007-2008, 105 students, 35 students with grade-point averages or GPA of
1.00 to 1.99 and grouped as high ability (HA), 35 students with GPA 2.00 to 2.99 and grouped as middle ability (MA) and another 35 students with GPA 3.00 and above, grouped as low ability (LA).

**Instrument**

To find out the factors affecting academic performance among first year nursing students, a validated and reliable instrument, adopted and utilized by Sansgiry (2006) in one of his studies, was used in this study as the principal technique in gathering data.

The instrument was a combination of five different questionnaires for five variables; academic competence, test competence, time management, studying techniques, and test anxiety. Each of the five questionnaires was composed of five questions that measured the students’ AC, TC, TM, ST, and TA, as students accomplished the questionnaires at once in the most convenient place in their most convenient time. The GPA, CHEM, AC, TC, TM, ST, and TA were used as codes in the statistical analyses.

**Data Collection**

Prior to conducting the study, permission to conduct study was asked from the school administrators. After the second semester of academic year 2007-2008, the university portal was accessed to gather the respondent-students’ grades during the said period. The respondents were made to realize the significance of administering the questionnaire, in order to solicit honest and genuine responses.

On the first month of this period, the instrument was administered to the students. The instrument was administered for a period of three weeks and the responses were carefully tallied and tabulated.
Data Analysis

Computerized data processing of this research was done with the use of SPSS Version 5. The arithmetic mean, standard deviation, and coefficient of variation of the students’ Chemistry grades and grade-point averages or GPA were computed and interpreted (OLFU Student Handbook, 2006).

To determine the correlations among the variables Chemistry achievement, academic performance, the five performance variables AC, TC, TM, ST, and TA, and the OPS, the Pearson product-moment coefficient of correlation was used. To examine all possible equations and select the best predictors, non-stepwise multiple linear regression was used. To test whether the variables taken together serve as significant predictors, ANOVA was employed.

Results and Discussion

The main objective of this study was to determine and predict the predictors of Chemistry performance and academic performance among first year nursing students. Table 1 shows that out of 105 respondents, 55.24% were females, while 44.76% were males. The higher percentage in females may be attributed to the fact that students taking up Nursing were mostly females.

Table 1

Frequency Distribution of the Respondents as to Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency (f)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>58</td>
<td>55.24</td>
</tr>
<tr>
<td>Male</td>
<td>47</td>
<td>44.76</td>
</tr>
<tr>
<td>Total</td>
<td>105</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 shows equal distribution of respondents according to ability. Out of 105 respondents, 33.33% were grouped as high ability (HA), 33.33% were grouped as middle ability (MA), and 33.33% were grouped as low ability (LA).

Table 2

*Frequency Distribution of the Students According to Ability*

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency (f)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>35</td>
<td>33.33</td>
</tr>
<tr>
<td>Middle</td>
<td>35</td>
<td>33.33</td>
</tr>
<tr>
<td>Low</td>
<td>35</td>
<td>33.33</td>
</tr>
<tr>
<td>Total</td>
<td>105</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows the above average Chemistry achievement of the HA students with a mean of 1.78 and a standard deviation of 0.32, average of the MA students with a mean of 2.59 and a standard deviation of 0.48, and below average of the LA students with a mean of 4.69 and a standard deviation of 0.76. The HA students were most intact while the LA students were least intact. The HA students were most homogeneous while most heterogeneous was also the LA group.

Table 3

*Chemistry Achievement (CHEM) of the Respondents*

<table>
<thead>
<tr>
<th>Ability Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>1.78</td>
<td>0.32</td>
<td>Above Average</td>
</tr>
<tr>
<td>Middle</td>
<td>2.59</td>
<td>0.48</td>
<td>Average</td>
</tr>
<tr>
<td>Low</td>
<td>4.69</td>
<td>0.76</td>
<td>Below Average</td>
</tr>
<tr>
<td>Overall</td>
<td>3.02</td>
<td>1.35</td>
<td>Average</td>
</tr>
</tbody>
</table>

Table 4 shows the academic performance of the respondents which was the same as their Chemistry achievement. The HA students had above average academic performance with a mean of 1.69 and a standard deviation of 0.22, the MA students had average with a mean of 2.37 and a standard deviation of 0.13, and the LA students had below average
academic performance with a mean of 3.37 and a standard deviation of 0.35. The most homogeneous was the MA group and the LA group was most heterogeneous. This result supports the findings of Walter and Latta (2003) in their studies which revealed the better performance of high ability students than the lower ability students. The results also agree with the findings of Stewart and Liddle (2003) in their study where the high ability student nurses performed better than low ability students. But these results disagree with Pemberton's (2000) findings in his study, where the underachievers obtained higher performance than the overachievers. This suggests that the high ability students do not, in all cases, perform better than the lower ability students.

Table 4

<table>
<thead>
<tr>
<th>Ability Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>1.69</td>
<td>0.22</td>
<td>Above Average</td>
</tr>
<tr>
<td>Middle</td>
<td>2.37</td>
<td>0.13</td>
<td>Average</td>
</tr>
<tr>
<td>Low</td>
<td>3.37</td>
<td>0.35</td>
<td>Below Average</td>
</tr>
<tr>
<td>Overall</td>
<td>2.48</td>
<td>0.73</td>
<td>Average</td>
</tr>
</tbody>
</table>

Table 5 shows that the respondents had positive TC and TM and moderately positive AC, ST, TA and OPS. The respondents were most homogeneous in terms of their OPS with a standard deviation of 0.45, and most heterogeneous in terms of TA with a standard deviation of 0.78.

A statistical analysis published in 1992 found that students of all ability levels benefit from grouping that adjusts the curriculum to the students’ aptitude levels. This may be the reason why the scores on AC, TC, TM, ST, TM and OPS of the three groups of respondents used in this study, were generally positive to moderately positive. This is consistent to Spear’s (1992) theory that since heterogeneous grouping is a mix of various abilities and traits, students of different abilities have opportunities to work with students of various
emotional, intellectual and physical developments. While Straham (2000) further emphasized that heterogeneous grouping allows students to socialize with, model and adjust to a variety of peer influence.

Table 5

Summary of Respondents’ Academic Competence (AC), Test Competence (TC), Time Management (TM), Studying Techniques (ST), Test Anxiety (TA), and Overall Performance Score (OPS) Ability Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Response</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Competence (AC)</td>
<td>1.85</td>
<td>0.53</td>
<td>Agree</td>
<td>Moderately Positive</td>
</tr>
<tr>
<td>Test Competence (TC)</td>
<td>2.63</td>
<td>0.59</td>
<td>Neither</td>
<td>Positive</td>
</tr>
<tr>
<td>Time Management (TM)</td>
<td>2.78</td>
<td>0.74</td>
<td>Neither</td>
<td>Positive</td>
</tr>
<tr>
<td>Studying Techniques (ST)</td>
<td>2.26</td>
<td>0.56</td>
<td>Agree</td>
<td>Moderately Positive</td>
</tr>
<tr>
<td>Test Anxiety (TA)</td>
<td>2.30</td>
<td>0.78</td>
<td>Agree</td>
<td>Moderately Positive</td>
</tr>
<tr>
<td>Overall Performance Score (OPS)</td>
<td>2.36</td>
<td>0.45</td>
<td>Agree</td>
<td>Moderately Positive</td>
</tr>
</tbody>
</table>

Table 6 shows the correlations among the variables which ranged from low to marked substantial, except between ST and CHEM and TA and ST with negligible correlation. This suggests that each paired variable correlated with each other in different degrees. Tested at 0.05 level, significant relationships exist mostly in paired variables. This means that in these paired variables, the students’ remarks in one results to the same remarks in the other.

A highly significant relationship exists between CHEM and GPA which proves that good grades in Chemistry, as a difficult subject for most nursing students, will give a student a positive overall academic performance. The results of the study support results of Coll (2002) where his analyses revealed that the performance of students is related to their attitude towards Chemistry, self-efficacy and learning experiences.
There was moderate correlation between TA and TM. This differs from Sansgiry’s (2006) results, where test anxiety among students was negatively correlated with their ability to manage time. The moderate correlation between GPA and TM on the other hand supports the conclusion of Trueman and Hartley (2004) when they compared the performance of students of different time management skills. In their study, older students had better time management skills students and perform better than the two other groups of younger men and women.

Although there was low correlation between TA and TC, this disagrees with Sansgiry’s (2006) where students’ test anxiety had positive correlation with students’ perceptions of course load. This finding also supports Dales’ (2003) theory that test anxiety, brought by a number of reasons, makes a great influence on the students’ struggles in different subjects, and is a major predictor of their academic success. Though only low correlation exists between ST and GPA of the respondents used in this study, it agrees with Okit’s (1994) results that revealed high scores on study habits correlated with good grades. The low correlation between AC and GPA of the respondents agrees with Sansgiry’s (2006) results in one his studies that revealed students’ academic competence and academic performance were correlated.

There was no correlation between CHEM and ST, which disagrees with most studies about the significant effect of good study habits and techniques on the academic performance of the students as a whole. Kizlik (2008) said poor study skills result to low or failing grades and pointed out that success in college depends on students' study skills. Students therefore must implement a variety of learning strategies (Mc Guire, 2002).
Table 6

**Correlations among the Respondents’ CHEM, GPA, AC, TC, TM, ST, TA and OPS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>GPA</th>
<th>CHEM</th>
<th>AC</th>
<th>TC</th>
<th>TM</th>
<th>ST</th>
<th>TA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM</td>
<td>0.88**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC</td>
<td>0.32**</td>
<td>0.23*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>0.30**</td>
<td>0.25**</td>
<td>0.44**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM</td>
<td>0.40**</td>
<td>0.28**</td>
<td>0.44**</td>
<td>0.64**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST</td>
<td>0.21*</td>
<td>0.16</td>
<td>0.45**</td>
<td>0.26**</td>
<td>0.30**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TA</td>
<td>0.27**</td>
<td>0.21*</td>
<td>0.27**</td>
<td>0.31**</td>
<td>0.47**</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>OPS</td>
<td>0.43**</td>
<td>0.32**</td>
<td>0.69**</td>
<td>0.74**</td>
<td>0.83**</td>
<td>0.58**</td>
<td>0.68**</td>
</tr>
</tbody>
</table>

Table 7 shows the regression summary for the predictors of Chemistry achievement (CHEM). The performance variables AC, TC, TM, ST, TA, and the OPS are potential factors to affect Chemistry achievement of the students. But OPS is of best potential, followed by AC, TM, TC, TA, and ST. The regression equation, given by \( \text{CHEM}_y = 0.8745 + 0.2611_{(\text{OPS})} + 0.1669_{(\text{AC})} + 0.1662_{(\text{TM})} + 0.1521_{(\text{TC})} + 0.1020_{(\text{TA})} + 0.0546_{(\text{ST})} \) with adjusted \( R^2 = 4.56 \% \), means that the variation in the Chemistry achievement is explained by the independent variables AC, TM, TC, TA, ST, and OPS. But the model variables are not significant because taken individually, it could be noticed that the p values are not less than 0.01.

Table 7

**Regression Summary for Chemistry Achievement (CHEM)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>Std. Error</th>
<th>t (98)</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.8745</td>
<td>0.7152</td>
<td>1.2228</td>
<td>0.2244</td>
</tr>
<tr>
<td>AC</td>
<td>0.1669</td>
<td>0.3151</td>
<td>0.5297</td>
<td>0.5975</td>
</tr>
<tr>
<td>TC</td>
<td>0.1521</td>
<td>0.3043</td>
<td>0.5000</td>
<td>0.6182</td>
</tr>
<tr>
<td>TM</td>
<td>0.1661</td>
<td>0.2679</td>
<td>0.6203</td>
<td>0.5365</td>
</tr>
<tr>
<td>ST</td>
<td>0.0456</td>
<td>0.2853</td>
<td>0.1912</td>
<td>0.8488</td>
</tr>
<tr>
<td>TA</td>
<td>0.1021</td>
<td>0.2272</td>
<td>0.4492</td>
<td>0.6543</td>
</tr>
<tr>
<td>OPS</td>
<td>0.2611</td>
<td>0.7655</td>
<td>0.3411</td>
<td>0.7338</td>
</tr>
</tbody>
</table>

\( R = 0.3172 \) \( R^2 = 0.1006 \) \( \text{Adjusted } R^2 = 0.0456 \)
Table 8 shows the ANOVA summary table for Chemistry achievement. As shown on the table, the difference in the students’ Chemistry achievement is not significant. The performance variables AC, TC, TM, ST, TA, therefore, when taken altogether or as a group, had likewise no significant relationship with the Chemistry achievement among the students, with obtained p value of 0.1015.

Table 8

*ANOVA Summary Table: Chemistry Achievement (CHEM)*

<table>
<thead>
<tr>
<th>Sources of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
<th>Probability (p)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>19.06</td>
<td>6</td>
<td>3.18</td>
<td>1.83</td>
<td>0.1015</td>
<td>Not Significant</td>
</tr>
<tr>
<td>Residual</td>
<td>170.34</td>
<td>98</td>
<td>1.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>189.39</td>
<td>104</td>
<td>1.74</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9 shows the regression summary for the predictors of academic performance. The performance variables AC, TC, TM, ST, TA, and the OPS are potential factors to affect academic performance of the students. But among the said variables, the OPS is of the best potential, followed by TM, AC, TA, TC, and ST. The regression equation is given by \( \text{GPA}_y = 0.9703 + 0.1896 \text{(OPS)} + 0.1788 \text{(TM)} + 0.1537 \text{(AC)} + 0.0595 \text{(TA)} + 0.0331 \text{(TC)} + 0.0232 \text{(ST)} \) with adjusted \( r^2 = 13.63 \% \), which means that the variation in the academic performance is explained by the independent variables AC, TC, TM, ST, TA, and OPS. The variables are highly significant because taken individually, it could be noticed that the p values are less than 0.01.
Table 9

Regression Summary for Academic Performance (GPA)

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>Std. Error</th>
<th>t (98)</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.9703</td>
<td>0.3694</td>
<td>2.6270</td>
<td>0.0100</td>
</tr>
<tr>
<td>AC</td>
<td>0.1537</td>
<td>0.1627</td>
<td>0.9447</td>
<td>0.3472</td>
</tr>
<tr>
<td>TC</td>
<td>0.0331</td>
<td>0.1571</td>
<td>0.2109</td>
<td>0.8334</td>
</tr>
<tr>
<td>TM</td>
<td>0.1788</td>
<td>0.1383</td>
<td>1.2921</td>
<td>0.1993</td>
</tr>
<tr>
<td>ST</td>
<td>0.0232</td>
<td>0.1474</td>
<td>0.1576</td>
<td>0.8751</td>
</tr>
<tr>
<td>TA</td>
<td>0.0595</td>
<td>0.1174</td>
<td>0.5069</td>
<td>0.6134</td>
</tr>
<tr>
<td>OPS</td>
<td>0.1896</td>
<td>0.3954</td>
<td>0.4796</td>
<td>0.6326</td>
</tr>
</tbody>
</table>

R = 0.4314  R² = 0.1861  Adjusted R² = 0.1363

Table 10, the ANOVA summary table for academic performance shows that there was significant difference in the academic performance among the students. This means that the performance variables AC, TC, TM, ST, TA, and the OPS, when taken altogether or as a group, had significant relationship with the academic performance of the students. The p value obtained was 0.002180. The performance variables, taken altogether or as a group, therefore were significant predictors of students’ academic performance. The five selected performance variables used in this study are nonintellective. The study’s results differ from those of the study conducted by Brown Hall (2008) where his revealed significant relationship between intellective factors and academic performance and nonsignificant relationship between nonintellective factors and academic performance.

From the study’s findings, it appeared that three of the independent variables, AC, TM, and OPS were the best or strongest predictors of Chemistry achievement and academic performance. These findings agree with Sansgiry’s results wherein academic competence was one of the important factors associated with academic performance. The results also support Di Perna (2001) in his study where he obtained moderate correlation between students’ score on an academic competence instrument and their academic performance. These also findings support Javier (2001) when she concluded that IQ or mental ability is not the only predictor of academic achievement, that there are many other factors that contribute to good
performance. They also support theory of Trueman and Hartley (2004) that older people have more experiences and therefore have better time management, and the study of Andrews’ (2006) where his results revealed that that time spent in paid employment was the strongest predictor of academic performance in nursing practice.

As Navarro (2003) pointed out, first year in college is crucial and characterized with doubt, fear and confusion, and that an intervention program will help them make proper adjustment. Mansfield (2002) theorized that college students face a myriad of pressures and challenges in the academic environment as they seek to maintain optimal performance or even to remain in the academic program. Poor time management unfortunately causes many first year college students to academically perform poorly. Findings of this study therefore agree with Lakein (2001), that effective time management is an important key to nursing students' academic success.

Table 10

ANOVA Summary Table: GPA

<table>
<thead>
<tr>
<th>Sources of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
<th>Probability (p)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>10.39</td>
<td>6</td>
<td>1.73</td>
<td>3.73</td>
<td>0.002180</td>
<td>Highly Significant</td>
</tr>
<tr>
<td>Residual</td>
<td>45.44</td>
<td>98</td>
<td>0.46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>55.83</td>
<td>104</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion and Recommendation

The first year nursing students enrolled at the time of the study had an average level of academic performance, their profile in terms of academic competence (AC), studying techniques (ST) and test anxiety (TA) is moderately positive, and positive in terms of test competence (TC) and time management (TM). Except studying techniques (ST) and test anxiety (TA), all the independent variables treated in the study correlated with each other, ranging from low to marked substantial, and highly significant relationships.
Highly significant factors as well affect students’ academic performance, as shown the first year the first semester’s GPA on AC, TC, and TM, while TA proved to be significant. ST was not a significant factor in the academic performance of the students. The revealed that TM is the best predictor of academic performance of students.

It is recommended that the university consider more strategic guidelines in creating heterogeneous classes/sections, conduct a follow-up study that will identify the causes of low scores yielded in the study, guidance counselors evaluate the study orientation of the first year students at the beginning of the school year so that the necessary assistance can be given to them at an earlier time and give seminars and develop programs that will focus on the independent variables used in this study, as the researcher’s study proved them to be potential predictors of academic performance., curriculum makers consider integration of lessons that will develop study habits among students, so that they can study more efficiently and effectively, and develop programs that will aim to help students of all courses attain high academic performance.

Acknowledgement

The researcher extends her sincerest gratitude to Dr. Jameson H. Tan for always supporting her in her research endeavor, her long-time mentor Dr. Rebecca C. Nueva Espana, her advisers Dr. Marilyn U. Balagtas and Dr. Marie Paz E. Morales, Senator Sherwin T. Gatchalian, Valenzuela City Mayor Rexlon T. Gatchalian, 1st District Congressman Wenceslao Gatchalian, 2nd District Congressman Eric Martinez, Vice Mayor Lorie Natividad-Borja for always granting financial support, her family and friends for inspiration, and the Almighty Lord for making all things possible.
References


Development of Metacognitive-Enhanced Learning Resource Materials in Molecular Genetics: Effects on Students’ Metacognition and Classroom Environment

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Abstract

Metacognition relates to thinking about one’s thinking. It refers to how an individual, especially learners, plan, monitor, and assess their understanding and performance. Metacognition promotes critical awareness of one’s thinking and learning. The study highlights the conceptualization, implementation, and evaluation of the Metacognitive-Enhanced Learning Resource Materials in Molecular Genetics (MELRMMG). The MELRMMG consists of four (4) learning modules that are carefully designed and planned corresponding to specific topics in molecular genetics. All modules were structured in such a way that the students will become aware of their thinking in line with the concepts in molecular genetics. This is also in response to the research gaps identified by Zohar & Barzilai (2013) in their review of research on metacognition in science education: a) attention to the development of learners’ metacognitive knowledge and b) controlled research designs providing causal evidence regarding the effectiveness of metacognitive instruction in science learning.

The Plan-Do-Study-Act (PDSA) cycle approach was employed in the study. Both quantitative and qualitative research techniques were explored to answer the problems of the study. A total of ninety-five (95) Grade 10 students studying in an all-boys, Catholic private junior high school in the Philippines participated in the study. The students were exposed to different metacognitive activities as they learn and understand topics in molecular genetics: nature and characteristics of DNA, DNA replication, protein synthesis, and genetic mutations. Metacognitive prompts, journal reflection, concept mapping, and inquiry-based activities were some of the learning activities done by the students. Quantitative data were gathered using the Metacognitive Assessment Inventory (MAI) by Schraw and Dennison (1994) and the Metacognitive Orientation Learning Environment Scale-Science (MOLES-S) by Thomas (2003). Both instruments were given as pre- and post-assessments. Qualitative
data were gathered using the students’ responses in metacognitive prompts, reflections, and semi-structured interviews.

Results showed a significant effect on the enhancement on the students’ metacognitive skills and improvement on the metacognitive orientation of the classroom. The students, after being exposed to a metacognitive learning environment, became more aware on their thinking processes especially how they identify their learning challenges in molecular genetics. They were also equipped with the skills in self-regulated study techniques to address their learning challenges.

Furthermore, this study reinforces the critical links between science education, metacognition, and learning environments. There is a great need to develop and structure science classroom environments that are favorable to the development and enhancement of students’ metacognition. In turn, this will result to a thorough conceptual understanding of science topics, specifically those involving molecular level processes.

*Keywords*: metacognition, self-regulated learning, molecular genetics, learning environments, biology education
Development of Metacognitive-Enhanced Learning Resource Materials in Molecular Genetics: Effects on Students’ Metacognition and Classroom Environment

Much of the research work published in science education journals over the past decade has considered two areas of interest: curriculum change in science education and the use of multiple instructional strategies to improve learning (Schraw, Crippen, & Hartley, 2006). Metacognition has made significant implications on learning and instructions (Zohar & Barzilai, 2013). Teaching of metacognition is one of the main recommendations for improving instructions that emerged from over three decades of research on how people learn best (National Research Council, 2005; Zohar & Barzilai, 2013). A number of research work were done in the field of science education by integrating metacognition framework in instructional planning and curriculum development (Schraw et al., 2006; Zohar & Barzilai, 2013). It was further verified in the comprehensive meta-analyses study of Hattie (2009) that the most effective teaching approach involves strategies emphasizing learners’ metacognition and self-regulated learning.

Schraw et al. (2006) identified six general areas of instructional strategies for improving science learning. These areas are (a) inquiry based learning, (b) the role of collaborative support, (c) strategy instruction to improve problem solving and critical thinking, (d) strategies for helping students construct mental models and to experience conceptual change, (e) the use of technology, and (f) the impact of student and teacher beliefs.

One of the most common teaching strategies used in science classes is the inclusion of metacognitive prompts or cues (Zohar & Barzilai, 2013). According to Zhang, Hsu, Wang, & Ho (2015), the inclusion of metacognitive prompts along with cognitive prompts had significant impacts on the learners’ inquiry practices, especially to their analyzing and planning skills. They also found out that mixing metacognitive prompts with cognitive
prompts have a differential effect to learners with lower level metacognition, showing significant improvement in their inquiry abilities.

The study of Zepeda, Richey, Ronevich, & Nokes-malach (2015) reveals that direct instruction of metacognition in a science class can improve both cognitive and motivational aspects of learning. Their study involved using puzzle problems and integrating metacognition prompts in teaching physics. Another study conducted by Peters & Kitsantas (2010) verified the positive effects of integrating metacognitive prompts in science teaching. They embedded metacognitive prompts in teaching the nature of science to Grade 8 science students. The results of their study showed that the students who were exposed to metacognitive prompts have significant gains in terms of content knowledge and nature of science knowledge as compared to those who are under the control group.

The use of metacognition log, reflection log, or learning log is also a common strategy used in science classes (Zohar & Barzilai, 2013). The study of Stephens & Winterbottom (2010) explored the use of learning log in a high school biology class. They were able to find out that such kind of metacognitive teaching strategy can stimulate the students to reflect. However, their study did not prompt the students’ level of learning strategy awareness as elicited in the semi-structured interview conducted to the participants.

**Research Problems**

The goal of the study is to investigate the effectiveness of integrating a metacognitive-enhanced approach and self-regulated learning strategies in understanding molecular genetics. Specifically, it aims to answer the following questions:

1. How do students perceive the extent of applying and observing metacognitive practices in their science classes? Is there a significant difference on their perception of the science classroom orientation after they were exposed to a metacognitive-oriented learning environment?
2. Is there a significant difference on the students’ initial perception of their self-efficacy and metacognitive awareness after the intervention? To what extent have students manifested metacognitive behaviors

Methodology

Participants of the Study

The participants of the study were ninety-five (95) Grade 10 junior high school students who are taking the Science Program that include the Molecular Genetics in the curriculum. They were all exposed to different and varied learning instructions complying to the Metacognitive-Oriented Environment (MOE).

Research Instruments

The study utilized the following instruments: Metacognitive Orientation Learning Environment Scale-Science (MOLES-S) by Gregory Thomas (2003) and Metacognitive Assessment Inventory (MAI) by Gregory Schraw and Rayne Sperling Dennison (1994). Qualitative data were acquired from the Metacognitive Journal Logs, Focused Group Discussions, and Individualized Informal Interviews.

Data Gathering Procedures

The study was generally divided into four (4) phases coinciding to the PDSA cycle: Plan Phase: Development and Preparation of the Metacognitive-Enhanced Learning Resource Materials in Molecular Genetics (MELRMMG) and Varied Research Instruments; Do Phase: Adoption and Implementation of MELRMMG; Study Phase: Exploring and Analyzing the Effects of MELRMMG on the Learners’ Metacognition, Self-Efficacy, Conceptual
Knowledge on Molecular Genetics, and Views on the Metacognitive Learning Environment; and Act Phase: Completion of the First Cycle of the Study and Communication of Results.

**Plan Phase**

The Metacognitive-Enhanced Learning Resource Materials in Molecular Genetics (MELRMMG) was designed and created anchoring on the Self-Regulated Learning and Metacognition Framework, Constructivist Learning Framework, and Understanding by Design (UbD) Framework. The learning resource materials were evaluated by veteran Science teachers who also have backgrounds on metacognition. The MELRMMG was structured and designed in such a way that will allow the students to be aware of their thinking in line with the genetics concepts. Learning activities were designed to activate their prior knowledge along with planning, monitoring, and evaluating their conceptual understanding on the different topics per module.

**Do Phase**

Before implementing the learning activities, the participants were asked to accomplish the following instruments: Metacognitive Orientation Learning Environments Scale – Science (MOLES – S), Metacognitive Awareness Inventory (MAI), Self-Efficacy and Metacognition Learning Inventory-Science (SEMLI-S), and the Two-tier Molecular Genetics Concept Test (TMGCT) as pretests.

After taking the pretests, the participants were then exposed to the instructional interventions under the Metacognitive-Oriented Environment (MOE). All students were provided copies of the MELRMMG modules through a portable document format (pdf) file. They were also encouraged to use their gadgets like tablet or laptop, so they can refer to modules during class sessions. The participants underwent metacognitive instructional practices like metacognitive prompts, reflective writing, teacher-led metacognitive
discussions, student-led metacognitive discussions, explicit instruction, use of ICT for metacognitive instruction, concept mapping, and metacognitive modelling by the teacher. All activities were outlined in the MELRMMG Teacher’s Module. Daily activities per session were set and identified. The whole adoption and implementation of the modules lasted for twenty-one (21) sessions. However, unforeseen events like suspension of classes due to inclement weather affected the continual flow of the implementation. After the intervention, the students were asked to take the post-tests of the different instruments: MOLES–S, MAI, SEMLI-S, and the TMGCT. The results were analyzed and compared to the pretests in order to obtain substantial quantitative data.

After the post-tests, each class section underwent a Focused Group Discussions (FGD) in order to obtain qualitative feedbacks from their experiences in learning molecular genetics MOE. Structured questions were developed by the researcher and participants were asked to answer them. There were individual informal interviews conducted on random days to prompt and assess the learning performance of the students.

An external class observer was invited to assess and evaluate whether the classroom learning environment has been set to a metacognitive orientation or not. The Science Subject Area Coordinator (SAC) was invited to conduct classroom observations during the implementation of each module.

Study Phase

Both quantitative and qualitative data were explored and analyzed to determine the effects of MOE to the participants of the study. Quantitative data includes the pretest and posttest scores of MOLES–S, MAI, SEMLI-S, and TMGCT. The pretest and posttest mean scores of the different constructs of each research instrument were determined and compared in order to assess the effectiveness of the intervention.
Act Phase

After careful analysis of the data gathered, the results were communicated to the Science teachers of the host school where the study was conducted. This was done in one of their faculty development sessions. The inputs were acknowledged and taken into consideration for the enhancement of the existing metacognitive-enhanced modules in molecular genetics, at the same, the results will be used as bases for curriculum development and policy-making procedures of the school.

Results and Discussions

Research Problem 1: How do students perceive the extent of applying and observing metacognitive practices in their science classes? Is there a significant difference on their perception of the science classroom orientation after they were exposed to a metacognitive-oriented learning environment?

Table 1

**Paired Samples t-Test on the Pre-test and Post-test Scores on MOLES-S**

<table>
<thead>
<tr>
<th>Variable</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOLES-S (Pre-test &amp; Post-test)</td>
<td>-4.860</td>
<td>85</td>
<td>.000</td>
<td>0.50</td>
</tr>
</tbody>
</table>

*Note: N = 86; p-value = 0.05 level; effect size (Cohen’s d) value 0.20 (small effect), 0.50 (medium effect), and 0.8 (large effect).*

Table 1 shows that the students’ perception of the metacognitive orientation of the science classroom significantly changed after being exposed under MOE (M = 3.98, SD = .53) as compared to their previous perception of their science classroom setting (M = 3.73, SD .53, t(85) = -4.860, p < .05, r = 0.22). The intervention also resulted to a medium effect
size on the mean scores in MOLES-S. This can be attributed to the different learning activities included in the MELRMMG which they have engaged in during the whole implementation of the modules.

One of the learning activities done during the implementation of the modules was the use of metacognitive prompts. Each MELRMMG module includes prompts that were designed fitting the topic. Their responses showed that the students were able to activate their reflective state of thinking by describing, planning, and evaluating how they went through their understanding of the molecular genetics concept. One of the metacognitive prompt activities done was the accomplishment of a Know-Want-Learn (KWL) Chart. In this metacognitive activity, students were asked to fill out the ‘What I KNOW’ and ‘What I WANT to know’ columns prior to the discussion of the topic. The responses also served as a diagnosis on students’ preconceived notions about molecular genetics. After the discussion and execution of the learning activities, students were instructed to complete the third column of the KWL chart: ‘What I LEARNED.’ Below are some representative responses of students in the KWL chart on the nature and characteristics of DNA molecule:

Student CAN22:

<table>
<thead>
<tr>
<th>What I KNOW</th>
<th>What I WANT to know</th>
<th>What I LEARNED</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA is used as genetics to keep our physical traits</td>
<td>what is DNA structures</td>
<td>A nucleotide has a sugar, a phosphate group, a nitrogenous base</td>
</tr>
<tr>
<td>DNA is part of nucleic acids</td>
<td>how does it work</td>
<td>DNA has adenine, guanine, thymine, and cytosine</td>
</tr>
<tr>
<td>DNA has mitosis</td>
<td>what is RNA</td>
<td>DNA is double strand</td>
</tr>
</tbody>
</table>

Figure 1. Written Responses of Student CAN22 in the KWL Chart Activity.
The responses of Student CAN22 on the first column manifested misconceptions about the functions and characteristics of DNA molecule. Although the topic is relatively new to him, he was already exposed to the pre-requisite topics needed to understand molecular genetics. Back in Grade 9, he already encountered the concepts about chromosomes and cell division process, hence, the inclusion of mitosis in the first column. After the exposure to metacognitive environment, his responses on the third column manifested specific and more factual concepts about the DNA molecule.

Table 2
*Paired Samples t-Test on the Pre-test and Post-test Scores of all the Constructs included in MOLES-S*

<table>
<thead>
<tr>
<th>Constructs</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive Demand</td>
<td>-4.880</td>
<td>85</td>
<td>.000</td>
<td>0.53</td>
</tr>
<tr>
<td>Student-Student Discourse</td>
<td>-2.376</td>
<td>85</td>
<td>.020</td>
<td>0.23</td>
</tr>
<tr>
<td>Student-Teacher Discourse</td>
<td>-2.425</td>
<td>85</td>
<td>.017</td>
<td>0.24</td>
</tr>
<tr>
<td>Student Voice</td>
<td>-3.056</td>
<td>85</td>
<td>.003</td>
<td>0.41</td>
</tr>
<tr>
<td>Distributed Control</td>
<td>-2.107</td>
<td>85</td>
<td>.038</td>
<td>0.24</td>
</tr>
<tr>
<td>Teacher Encouragement and Support</td>
<td>-4.535</td>
<td>85</td>
<td>.000</td>
<td>0.55</td>
</tr>
<tr>
<td>Emotional Support</td>
<td>-3.005</td>
<td>85</td>
<td>.003</td>
<td>0.23</td>
</tr>
</tbody>
</table>

*Note: N = 86; p-value = 0.05 level; effect size (Cohen’s d) value 0.20 (small effect), 0.50 (medium effect), and 0.8 (large effect).*

The different constructs in orientating a metacognitive classroom were examined and all showed a significant increase (p < 0.05) on the means scores after being exposed to MOE. The results confirmed that the adoption and implementation of the MELRMMG adjusted and improved the metacognitive orientation of the science classroom. The students’ exposure to
MOE allowed them to become aware of how they learn best, initiate discussions of their science learning processes with their classmates and teacher, voice out concerns on the teaching methodologies, collaborate with the teacher on the teaching approaches and methodologies, and promote encouragement and emotional support towards their classmates and teacher. The results further confirmed that the use of MELRMMG in the classroom satisfied the standard set by Thomas (2003) for a metacognitive learning environment: students must be acknowledged as essential functionaries who are honing their abilities to transform and interpret information along with monitoring their progress.

Research Problem 2: Is there a significant difference on the students’ initial perception of their self-efficacy and metacognitive awareness after the intervention? To what extent have students manifested metacognitive behaviors?

Table 3
Paired Samples t-Test on the Pre-test and Post-test Scores on MAI

<table>
<thead>
<tr>
<th>Variable</th>
<th>$t$</th>
<th>$df$</th>
<th>$p$</th>
<th>Cohen’s $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAI (Pre-test &amp; Post-test)</td>
<td>-3.472</td>
<td>85</td>
<td>.001</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Note: N = 86; p-value = 0.05 level; effect size (Cohen’s d) value 0.20 (small effect), 0.50 (medium effect), and 0.8 (large effect).

After being exposed to MOE, the students have significantly increased their metacognitive awareness mean scores ($t$(85) = -3.472, $p < .05$, $r = 0.12$) as evident in their pre-test ($M = 3.59$, $SD = .46$) and post-test mean scores ($M = 3.71$, $SD = .43$). These findings are attributed to their exposure of the MOE with the use of the MELRMMG modules. As they were exposed to different metacognitive activities, their perceptions of their metacognitive skills and awareness were enhanced and improved. The results also confirmed
the findings of Aurah (2013) where she established that exposure to metacognitive activities improves students’ metacognition in learning Biology.

A metacognitive log was given to the students at the end of each module. This allowed the students to reflect and write down their thoughts and even challenges encountered as they went through understanding molecular genetics. The responses were coded and categorized to arrive at specific themes. The categories were adapted from study of Zohar and Barzilai (2013) where they have identified the components of metacognition: Metacognitive Knowledge, Metacognitive Skills, and Metacognitive Experiences.

### Table 4

**Matrix of Qualitative Responses of Students on Their Metacognitive Awareness**

<table>
<thead>
<tr>
<th>Students’ Responses</th>
<th>Code</th>
<th>Categories</th>
<th>Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student GAT6:</strong> “I would describe it [thinking] as moderate, because it is quite hard to process and understand the current lesson with that amount of information.”</td>
<td>moderate; hard to process; amount of information</td>
<td>Metacognitive Knowledge</td>
<td><strong>Theme 1</strong> Awareness and consciousness of one’s cognitive and metacognitive state leads to a more resolved state of self-efficacy.</td>
</tr>
<tr>
<td><strong>Student GAT3:</strong> “I had to really work hard to understand and remember the different terms. I had to read my books and notes everyday, but I also had to sacrifice my rest time.”</td>
<td>work hard; sacrifice</td>
<td>Metacognitive Skill</td>
<td><strong>Theme 2</strong> Responsiveness to address learning distractions, difficulties, and challenges results to one’s confidence in understanding complex scientific concepts.</td>
</tr>
<tr>
<td><strong>Student GAT28:</strong> “Even if I’m tired, I forced myself to obtain and digest the concepts and I also read my notes after discussion to help me remember them. I treated them as something I can’t not [sic] think about daily.”</td>
<td>tired; obtain and digest concepts; remember</td>
<td>Metacognitive Skill; Metacognitive Experience</td>
<td></td>
</tr>
<tr>
<td><strong>Student GAT24:</strong> “Distracted. Since Science is the last subject, I begin to feel sleepy, so I find distractions to keep me up.”</td>
<td>distracted</td>
<td>Metacognitive Experience</td>
<td></td>
</tr>
<tr>
<td><strong>Student CAN19:</strong> “It was really difficult to link 2 nearly similar topics because I would get confused and I would mix up terms.”</td>
<td>difficult; confused; mix up terms</td>
<td>Metacognitive Knowledge; Metacognitive Experience</td>
<td></td>
</tr>
</tbody>
</table>

Students responses showed how much they are open and sincere in sharing their thoughts and insights about their learning processes. The metacognitive logs were considered
as homework and usually given at the end of each module. The responses revealed their study habits and disposition towards the subject. Under the metacognitive experience category, students have become in touch with their emotions and feelings and how both affect their cognitive processing. This in turn relates the kind of learning environment that does not only focus on conceptual understanding but also affective development. Through the affective domain, students can hone further their self-efficacy and confidence to learn and appreciate science.

**Conclusions and Educational Implications**

The increasing number of studies on metacognition only proves its significance and relevance in improving current teaching practices in science education. There has been numerous studies proving the effectiveness of metacognitive activities in attaining scientific conceptual understanding and improving self-efficacy of students (Aurah, 2013; Peters & Kitsantas, 2010; Thomas & Au Kin Mee, 2005; Veenman & Kok, 2005). What makes this study unique is that it has laid a baseline data that includes and conforms to the metacognitive context and background of Filipino students vis-à-vis the current Philippine science education system. With this, Filipino science teachers can already have a more suited model on how to integrate metacognitive practices in their classes.

With the resounding finding that students’ exposure to the Metacognitive-Oriented Environment (MOE) significantly increased their levels of metacognitive awareness in learning molecular genetics, there is greater need to promote and advocate such kind of teaching approach inside the classroom. The use of Metacognitive Enhanced Learning Resource Materials in Molecular Genetics (MELRMMG) was effective in setting and structuring the standards for a metacognitive-oriented learning environment in Science. Its ease of implementation provides a distinguishable instructional resource that can easily be integrated and tailor-fit to pre-existing lesson plans, teaching guides, and curriculum guides.
of science teachers. Aside from teaching benefits, students also have access to pertinent concepts in molecular as they hone and develop their metacognitive skills and self-efficacy in science. The limited availability of metacognitively-inclined learning materials in molecular genetics or science in general has already been addressed by this study.
References


Assessment on the Conceptual Learning in Elementary School Electrical Activities

Via Manufacturing Scientific Toys

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Abstract

The purpose of the study was the assessment on the conceptual learning in elementary school electrical activities via manufacturing scientific toys. The class had the 25 students in the elementary school in New Taipei city, Taiwan. Students were all willing to participate and had considerable interest in learning circuit scientific concepts and practical courses. The study planned 6 lessons in 40 minutes per session in 3 weeks. The study was to teach of circuit scientific concepts, and performance assessment of scientific toys. The study analyzed the process that the students learned circuit scientific concepts and assembled scientific toys, to via performance assessment and semi-structure interview. The results of this study include:(1) The curriculum design of scientific toy can improve students' motivation for conceptual learning. The semi-structure interview disclosed that students will help each other in the toys assembly in order to launch and enjoy the competition derived from electrical concepts of interest. (2) It was justified that students were able to apply the learned concepts by the researcher’s introduction of the operation of the scientific toys. (3) The researcher found that students completed the design and validated scientific concepts in short time, and spent long time in the assembly of the scientific toys. It revealed that more comprehensive skills need to be cultivated during the process from learning to implementation of the concepts. (4) After the assembly of the scientific toys, the researcher continued to test the students with both paper and manufacturing tests, and the students can say at least more than 3 causes and find and solve the possible issues during the manufacturing activities.

Keywords: Scientific Toys, Performance Assessment, Conceptual Learning
Development of Metacognitive-Enhanced Learning Resource Materials in Molecular Genetics: Effects on Students’ Metacognition and Classroom Environment

In recent years, the maker movement is an important issue in science education. Countries around the world have invested a large amount of resource and funds consecutively, vigorously promoted the maker movement, and hope to increase the talent of science and technology and promote the country’s economic development. Project 2061 defines science literacy broadly, emphasizing the connections among ideas in the natural and social sciences, mathematics, and technology (AAAS, 2013). AAAS pointed out that nature of technology will improve our ability to change the world, and it shows that learners’ attitudes, skills and thinking model will influence the scientific literacy of individuals.

Research and development are important scientific and technological research and development. The tenth article of the Science and Technology Competency Standard set by the International Association for Science and Technology Education (ITEA) clearly states that students’ technological capabilities in design should experience how to proceed through problem-solving activities: failure detection, research and development, innovation and improvement, and experimentation (ITEA, 2003).

Traditional teach method emphasizes memory and repeated practice, and it is not suitable for a new era of knowledge explosion. Teaching should be changed in order to cultivate students' high-level cognitive ability in modern teaching methods. In other words, current teaching activities should not only focus on knowledge, understanding, and application, but should also emphasize the ability to analyze, integrate, and evaluate.

Therefore, scientific toys can be used in teaching, with crosscutting learning, opportunities for students to explore and discover, scientific process skills, and scientific literacy. The maker movement is the core concept of this research. The "electrical irritating
maze" scientific toy has achieved crosscutting learning and guides students in learning science.

**Literature Review**

**Conceptual Learning**

The meaning of schema represents the worldview involved in the process of knowledge construction. Knowledge is the rationalization or practicality of learner experience, and it is also the consensus of learners interacting and negotiating with others (von Glasersfeld, 1991). The construction of new knowledge will be influenced by previous knowledge. Unless there is evidence or experience that the pre-conception is wrong, or to prove that the new scientific concept can explain the natural phenomenon around life more reasonably than the pre-conception did, the student will not easily change the pre-conception (Posner, Strike, Hewson, & Gertzog, 1982). Advocating teaching must be based on students' pre-conception, help students to construct scientific concepts, or guide students to change pre-conception. (Duit & Treagust, 1995). Teachers must understand the concepts that students already have before helping them to learn.

The student's pre-conception plays an important role in conceptual learning. Students' study emphasizes the exploration of scientific concepts, and the link between life experience and scientific concepts, and provides students with “clarification”, “debate”, “consolidation” and “elaboration” scientific concepts at appropriate time (Cosgrove & Osborne, 1985).

de Boo and Asoko (2000) suggest using models, metaphors, and diagrams to help students easily understand complex and abstract scientific principles. Newton (2002) proposes that circuit games can help students strengthen their knowledge of electricity. Scientific concepts have abstract and microscopic characteristics, so conceptual learning is not easy to learn and understand. In helping students construct scientific concepts, teachers often use various methods to convey concepts. Teachers must understand students’
constructive scientific knowledge through student’s feedback. Conceptual learning is an important learning objective of scientific learning. Students can produce an understanding of learning methods to form meaningful learning.

**Scientific Toys**

Vygotsky (1978) emphasizes that the game not only affects children's social and emotional development but also affects their cognitive development, and advocates that digital games have the ability to stimulate learning. In the process of science teaching activities, teachers need to act as supporting, guiding, and expanding roles based on students’ existing background knowledge. An important component of learning science is the development of a learning environment that promotes effective learning (learning environment; Sawyer, 2006). Collins (2006) use task-based learning as an example to implicate cognitive skills and knowledge in contexts so that learners not only acquire knowledge but also learn to use knowledge in situations. Students can learn through scientific toys and scientific games. Students can construct the concepts they want to learn. Scientific toys are helpful for the implementation of scientific teaching activities and can effectively improve students’ scientific literacy (Lai & Wang, 2010).

Teaching of scientific toys is a comprehensive assessment of knowledge, skills, and attitudes. It is suitable for performance assessment. Its advantages are: (1) Based on observation, dialogue and continuous operation, increase the effectiveness of the real situation. (2) The learner's attitude can be directly assessed. (3) It is suitable for collecting relevant data of students' learning process, which is conducive to formative assessment.

Scientific toys in teaching need to be planned in advance. Teaching must avoid intuitive, trial-and-error or over-open attempts. Curriculum design and teaching need to be goal-oriented. The design of teachers' teaching activities requires clarification of the learning
objectives, goal orientation, and understanding of the goals that can be achieved by their own instructional design.

**Performance Assessment**

The Next Generation Science Standards (NGSS) details the standards of K-12's scientific learning content at each stage, clearly pointing out that all students should develop staged scientific knowledge, develop the necessary capabilities for scientific inquiry and understand scientific inquiry. Teachers should continue to be committed in developing students' understanding. The main method is to conduct scientific teaching and learning through inquiry. Therefore, "inquiry" becomes the core of NGSS (National Research Council, 2000).

The main policies proposed by the OECD for student assessment include: (1) Ensure a good balance between formative and summative assessment. (2) Establish safeguards against an overreliance on standardized assessments. (3) Draw on a variety of assessment types to obtain a rounded picture of student, learning support effective formative assessment processes (OECD, 2013).

The improvement of teaching methods and assessment methods has been supported by many research literatures in the past. However, the concept of “teaching and evaluation should be collocated” is still an appeal among the scientific and educational communities (Bell, 2007; Britton & Schneider, 2007; Hickman, Isola, & Reif, 2008; William, 2008). True problem situations can arouse students' interest, but the situation of the problem must meet the scope of most students’ experience. With regard to precise content and standards, teachers can determine the scope of assessments through work, tasks and course analysis (Crocker, 1997; Dunbar, Koretz, & Hoover, 1991; Messick, 1995).

The situation provided by the performance assessment can be a simplified situation (Lesh & Doerr, 2003). Performance assessment emphasizes that students can use practical
skills and knowledge in the context of relevant issues (Stiggins, 1987). Wiggins (1998) pointed out that performance assessment should simulate real situations as much as possible, include accurate content and standards, and seduce students' performance. In the development of practical assessments, it is necessary to consider whether the standards for recording and scoring can determine the performance of students (Brualdi, 1998). The integrity of the actual evaluation depends on the perfect scoring criteria. The scoring standard is not only the standard of student ability, but also an important basis for the interpretation and application of the results. The perfect assessment made by a good scoring standard is equivalent to a good set of teaching (Airasian, 1994, 1996; Burger & Burger, 1994; Linn & Burton, 1994).

In summary, "performance assessment" is in a natural or constructed situation where teachers ask students to perform or process a designated job so that students can express their own learning results. The teacher will observe and evaluate the student's constructive response process and results. Performance assessment is a measure of direct judgment of performance. Therefore, the performance assessment can measure the process skills of combining knowledge and complex actions.

Methods

Participants

The class had the 25 students (11 to 12 years old) in an elementary school in New Taipei city, Taiwan. This study planned six lessons, 40 minutes per lessons. The study was to teach of circuit scientific concepts, and performance assessment of scientific toys. Teaching activities were scheduled after school club time. Students were all willing to participate and had considerable interest in learning circuit scientific concepts and practical courses.

Instruction Design

In the beginning of the lessons, the researcher motivated the students with the manufacturing of scientific toys. Researcher proceeded by the lectures of circuit scientific
concepts including open and closed circuits, and electric equipment in series and in parallel. Then, the introduction for the operation of “electrical irritating maze”, a maze enclosed by electrical circuits, guides students to draw their own electrical designs of such scientific toy, to explain, and to validate the drawn design. Lastly, the students assemble the scientific toys, assessed by the researchers with troubleshooting tasks.

The teaching of each lesson will be designed to measure the method. The teacher retains the assessment results in each course and provides student references at the end of the teaching activities. In this study, teachers are researchers. Through the recording process and results of performance assessment, students' conceptual learning and practical ability are analyzed.

Table 1

*Instruction and assessment design*

<table>
<thead>
<tr>
<th>Class</th>
<th>Instruction Content</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(1) Recognize the basic type of circuit</td>
<td>open circuit, closed circuit,</td>
</tr>
<tr>
<td></td>
<td>(2) Recognize the connection of the circuit.</td>
<td>circuit in series and parallel</td>
</tr>
<tr>
<td>2</td>
<td>Use mechanical tools to connect LEDs, batteries, and wire</td>
<td>Practice circuit connection</td>
</tr>
<tr>
<td>3</td>
<td>Draw a circuit diagram of a scientific toy (electrical</td>
<td>Draw the circuit diagram of</td>
</tr>
<tr>
<td></td>
<td>irritating maze) through hints</td>
<td>the scientific toy</td>
</tr>
<tr>
<td>4</td>
<td>Assemble the scientific toy (1)</td>
<td>Record student learning</td>
</tr>
<tr>
<td>5</td>
<td>Assemble the scientific toy (2)</td>
<td>Record student learning</td>
</tr>
<tr>
<td>6</td>
<td>Check scientific toys</td>
<td>Checklist</td>
</tr>
</tbody>
</table>
Analysis

This study analyzes the process that the students learned circuit scientific concepts and assembled the toys via recording, semi-structure interview, and performance assessment (checklist). This study is based on interpretative analysis of qualitative data to discuss the results of the study. (Table 2)

Table 2

*Checklist assessment standard of the scientific toy (electrical irritating maze)*

<table>
<thead>
<tr>
<th>Check item</th>
<th>3 point</th>
<th>2 point</th>
<th>1 point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit diagram</td>
<td>Draw the circuit diagram completely</td>
<td>Partially draw the circuit diagram according to the hint</td>
<td>Cannot draw circuit diagram</td>
</tr>
<tr>
<td>Circuit diagram match toy</td>
<td>Completely match</td>
<td>Partially match</td>
<td>Invalid circuit</td>
</tr>
<tr>
<td>Circuit parts test</td>
<td>Switch, LED, buzzer</td>
<td>Switch, LED, buzzer</td>
<td>Switch, LED, buzzer</td>
</tr>
<tr>
<td></td>
<td>stable</td>
<td>unstable</td>
<td>no use</td>
</tr>
<tr>
<td>Troubleshooting tasks</td>
<td>Say 3 items that are not valid when tested</td>
<td>Say 1 or 2 items that are not valid when tested</td>
<td>Cannot say items that are not valid when tested</td>
</tr>
</tbody>
</table>

This study conducted a qualitative analysis through a semi-structured interview. The researchers raised three questions to the study participants: (1) Do you like these lessons? (2) Why do you like these lessons? (3) What do you think is the most difficult part of these lessons?

This study selected study participants based on student performance checklist, and classifies students into three categories through the checklist score: complete understanding.
(above 10 points), partial understanding (6 - 9 points), and lack of understanding (less than 5 points). Two students from each category were selected for the interview. Students who are interviewed will be numbered, with the first code representing Student “S” and the second code representing the serial number.

Results and Discussion

Performance Assessment

The performance assessment of this study is divided into several parts: "Circuit diagram", "Circuit diagram match scientific toy", "Circuit parts test" and "troubleshooting tasks". According to the observation record and checklist, the analysis is listed below:

Circuit Diagram

At the end of the two courses (80min each), the students completed the circuit diagram of the scientific toy according to the hint of the lecture. Students could either complete the circuit diagram alone or discuss with their classmates.

\[\text{Figure. 1. Draw the circuit diagram completely according to the hint.}\]

\[\text{Figure. 2. Partially draw the circuit diagram according to the hint. And must be modified.}\]

After students completed the circuit diagram. The researcher gave the students a rate, and the students obtained the qualification to assemble a scientific toy. 19 students passed the “Draw a Circuit Diagram” test for the first time, and another 6 students were able to pass the test after the amendment.
Circuit Diagram Match Scientific Toy

Scientific toy is different from the circuit diagram, students spend longer time to assemble. After the assembly is completed, it must be compared with the "drawing circuit diagram" and the "scientific toy circuit".

![Figure 3. Scientific toy product.](image1)
![Figure 4. Top of scientific toy.](image2)
![Figure 5. Bottom of scientific toy.](image3)

The circuit diagram of 12 students is consistent with the scientific toy. The circuit diagram of 8 students is inconsistent with the scientific toy, but their scientific toys can work properly. In addition, 5 students could not complete the assembly of scientific toys and expressed that they did not understand the circuit diagram. At this stage, it shows that there are differences in students' learning effects of "circuit conceptual learning" and "operational assembly of scientific toys".

Students could understand the scientific concept of circuit diagrams, but they confessed that they could not understand the mapping between the top and bottom of scientific toys. For example, when an LED is put on the top of a scientific toy, it is difficult to find the corresponding position of the feet of the LED. Therefore, students cannot imagine circuits in three dimensions.

Circuit Parts Test and Troubleshooting Tasks

Researcher actually test student assembled scientific toys, and evaluate the accuracy and practicality of students’ scientific toy assembly. Within 15 students’ scientific toys, electronic components can operate stably. Within 5 students’ scientific toys, the operation of
electronic components occasionally becomes unstable, indicating that the internal circuit assembly is not properly connected.

In addition, when a problem occurs with a scientific toy, 18 students who can complete circuit diagrams and scientific toys can speak more than 3 items of inspection. It means that these 18 students can fully understand the relevance between scientific concepts and scientific toys, and solve the problems in the activity. (Table 3)

Table 3

*Performance assessment result*

<table>
<thead>
<tr>
<th>Check item</th>
<th>3 point</th>
<th>2 point</th>
<th>1 point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit diagram</td>
<td>19</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Circuit diagram match scientific toy</td>
<td>12</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Circuit parts test</td>
<td>18</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Troubleshooting tasks</td>
<td>11</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

*Figure 6. Performance assessment result.*
Semi-structure Interview

This study classifies students into three categories through the checklist score: complete understanding, partial understanding, and lack of understanding. (Table 4)

<table>
<thead>
<tr>
<th>Category of semi-structure interview</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
</tr>
<tr>
<td>complete understanding</td>
</tr>
<tr>
<td>partial understanding</td>
</tr>
<tr>
<td>lack of understanding</td>
</tr>
</tbody>
</table>

**Strong Motivation in Learning Circuit Scientific Concepts**

This study uses scientific toys as the goal of student learning. Scientific toys can stimulate students' interest in learning circuit concept.

I know that learning circuit diagrams can make scientific toys, so I am very interested in learning. (S1)

Because the learned knowledge is immediately applicable. I feel I can learn it quickly. (S3)

I am very serious in my studies, but it is really difficult and I cannot understand it. If I can, I will go back and try again. (S6)
Therefore, scientific toys in the activities can raise student’s motivation in learning. Even if students' learning is not effective, the weakening of learning motivation is not obvious.

**Differences between Concept and Practice**

The assessment of the scientific concept is simply based on calculations, graphics, and text tests. Students’ learning performance is also not easily seen. Through performance assessment, students can understand the relationship between their knowledge concepts and practice. For example, 19 students can draw circuit diagrams, but only 12 students can fully understand the relationship between circuit diagrams and scientific toys. In another example, 12 students had a complete electrical knowledge concept, but 18 students performed well in testing scientific toy operations.

I think that the assembly of scientific toys is difficult, and drawing circuit diagrams is very easy. I do not understand the transformation from plane diagram to three-dimensional structure. (S1)

I think that it is not difficult to draw circuit diagrams and scientific toy assembly concepts, but it takes a lot of time and is makes me feel tired to use tools to lock the boards and cut the plastic on the outer layers of the wires. (S2)

I don’t really understand the circuit diagram. However, I am familiar with assembling scientific toys, and I help my classmates to assemble theirs. Some of my classmates’ wires are also assembled by me. (S4)

If you teach me to assemble scientific toys, I am very interested and will not feel hard. But I think it's really hard to learn circuit serials, circuits in parallel and draw circuit diagrams. (S5)

I think the use of tools (wire stripper and screwdriver) in science courses is much more interesting than listening directly to scientific knowledge. (S6)
Therefore, integrating scientific toys into science education can support students in learning at different levels and in gaining learning stimuli.

**Conclusions**

**Performance Assessment can Record the Student's Learning Process**

Performance assessment includes the drawing of circuit diagrams and the process of assembling scientific toys. The assembly of scientific toys includes the use of tools (diagonal pliers, screwdrivers), parts arrangement of internal circuits, and troubleshooting. Researchers have found that students can complete drawing of circuit diagrams in a short period of time, proving that students can understand the scientific concept of electricity. Learning with scientific toys does not show scientific knowledge. It indicates that students have different ability to understand conceptual knowledge and scientific application.

**Scientific Toys can Effectively Improve Process Skills**

Researchers conduct semi-permanent assessments of students, and most students can express more than 3 items of the inspection for scientific toys. Students can find the causes of scientific toy malfunctions during operation and troubleshoot them. However, the description of scientific knowledge cannot be fully presented. The results of this study confirm the learning effect of hand-on scientific toys, and students' process skills ability is better than the understanding of scientific concepts.

**The Concept of Electricity can be Expressed Concretely**

Researchers recommend circuit diagrams for scientific toy circuit design. During peer discussions, students drew circuit diagrams of scientific toys on the study sheet, and described the circuit design nouns (open circuit, closed circuit, series circuit, parallel circuit)
on the design diagram. Researchers took a performance assessment of circuit conceptual learning. Some students can actually apply the concept of circuit learning.

**The Concept of Electricity Learning Motivation is Strong**

This study uses scientific toys as motivation factors for learning. It is expected to guide students to study actively and construct self-concept to be learned. In the teaching process, it is found that learning from peers can improve overall learning efficiency. Researchers conducted semi-structured interviews and students expressed the expectations that scientific toy assembly activities would be carried out as soon as possible. Students also like to help each other complete the circuit science concept.
References


An Empowerment Evaluation Approach in Shifting a South African Science Teacher Towards an Inquiry-Based Pedagogy

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Department of Science and Technology Education, University of Johannesburg,
Abstract

In South Africa, the introduction of inquiry-based instruction in a reformed science curriculum has met with serious challenges, such as the under-preparedness of in-service teachers. A shortcoming of in-service teacher education programmes is that these programmes do not engage with the contexts in which teachers work and the level of the existing capacity. This study reports on an empowerment evaluation approach to teacher development. Empowerment evaluation is a collaborative approach whereby individuals can achieve self-determination in their practice by becoming empowered to critically reflect on their practice, leading them to refining their practice. In this research, the researchers worked with a grade 9 Natural Sciences teacher in a rural school setting in South Africa. The goal was to empower the teacher in the introduction of an inquiry-based pedagogy informed by the 4Ex2 instruction model, which combines key components of inquiry instruction (Engage, Explore, Explain, Extend) with formative assessment and reflective practice integrated into each of the inquiry components. A case-study design was used. By employing the Electronic Quality of Inquiry Protocol (EQUIP) as a classroom observation tool, the researchers conducted six classroom observations, assessing the teacher on 19 indicators associated with inquiry spreading over four constructs: Instruction; Curriculum; Discourse and Assessment. In addition, stimulated recall discussions were used to enable the researchers the opportunity of seeing the classroom practices through the teachers’ eyes. The findings revealed that the deep reflection done by the teacher in the empowerment evaluation approach resulted in the teacher making significant changes to his lesson planning and classroom practice, and thereby shifting the teacher towards an inquiry-based pedagogy. The empowerment evaluation approach studied in this research thus offers a viable and sustained form of professional development that is likely to empower teachers in assessing, planning, implementing and evaluating what they do.
Keywords: empowerment evaluation; inquiry-based learning; teacher professional development
An Empowerment Evaluation Approach in Shifting a South African Science Teacher Towards an Inquiry-Based Pedagogy

In recent years, a common curriculum goal in school science education has been to encourage teachers to use scientific inquiry in their instruction as a means to advance learners’ understanding of scientific concepts, the processes of scientific investigation and the nature of science. Consequently, there has been much emphasis on developing science curricula that actively engage learners in an inquiry-based approach which requires them to do investigations. The National Curriculum Statement (Department of Education, 2003) of South Africa promulgates a learner-centred, inquiry-based science curriculum that is expected to transform classroom practices of teachers and learners’ learning environment. Such a curriculum advocates learner autonomy as it specifies that through investigations, teachers should ‘create opportunities for learners to demonstrate that they are able to work independently’ and encourage learners on their own to “explore objects, situations and events in their immediate environment, to collect data and record information and draw conclusions accurately” (Department of Education 2003, p. 34). Further to this, Specific Aim One of the latest Curriculum and Assessment Policy Statement states that the purpose of science is “to make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical phenomena” (Department of Basic Education, 2011, p. 8).

The active development of learner autonomy in an inquiry-based pedagogy re-defines the traditional teacher-learner relationship where the teacher is considered the expert who passes knowledge to passive learners. In facilitating inquiry-based learning, the teacher must consciously develop a classroom environment that is supportive and conducive to students doing their own investigations. Studies in South Africa (Ramnarain & Schuster, 2014; Rogan & Aldous, 2005; Seopa, Laugksch, Aldridge & Fraser, 2003) have revealed that despite curriculum imperatives for learners to have more autonomy in doing investigations, practical
work remains largely teacher controlled. This situation is contributed to largely by the teachers’ lack of experience in doing inquiry-based teaching, as they themselves have had only limited exposure to this pedagogy during their own pre-service studies (Tal & Argaman, 2005). This affects their capacity to mentor learners in inquiry which is characteristically learner-centred. Lotter, Harwood and Bonner (2006) recommend that professional development opportunities be designed, to help teachers to progress from traditional instruction to pedagogies incorporating inquiry. Teachers need to be the main agents for change and are pivotal for the success of any reform effort in school (Darling-Hammond & Bransford, 2006).

However, teachers have bemoaned the lack of substantive support from the South African Department of Basic Education (DBE) by expressing dissatisfaction with ‘the learning resources and the level of support they were given as well as the quality of training to which they were exposed’ (Kriek & Basson 2008). The training on the revised curriculum consisted mostly of once off workshops in which the new policies and terminology were explained, with very little offered in terms of professional development in content knowledge, pedagogical content knowledge or concrete examples of how to facilitate scientific inquiry (Kriek & Grayson 2009). It is against this background that we embarked on a study to investigate a sustained and collaborative effort at the professional development of teachers (Loucks-Horsley, Hewson, Love, Stiles & Mundry 2003; Supovitz & Turner 2000).

**Empowerment Evaluation**

Empowerment evaluation is an approach whereby individuals can achieve self-determination in their practice (Fetterman, 1996). This study investigated how this approach can support a Natural Sciences teacher to achieve self-determination in the implementation of an inquiry-based pedagogy. Empowerment evaluation is posited as an approach that can be exploited in South African schools to facilitate an on job, self- initiated professional
development that is environmental conscious and ongoing. Empowerment evaluation commences with ‘taking stock’ with an assessment of what a curriculum does and does not do. This is followed with ‘setting goals’ where the evaluatee agrees upon goals to achieve. In ‘developing strategies’ the evaluatee and evaluator agree on how credible data will be provided. Thereafter, they ‘document progress’, evaluate and improve. Accordingly, empowerment evaluation is “the use of evaluation concepts, techniques, and findings to foster improvement and self-determination” (p. 3), and, its primary purpose in this regard is to “help people help themselves” (Fetterman, 1996, p.5). Important facets of this evaluation thus include facilitation, advocacy, illumination, and liberation (Fetterman, 1996). Empowerment evaluators serve as coaches or facilitators in providing guidance and direction as needed. Advocacy entails helping evaluatees use credible data to present their case in an evaluation of their curricula. Illumination is an eye-opening and enlightening experience that brings about new insight or understanding about an issue or practice. Liberation follows illumination, and is the act of freeing oneself from preexisting roles and constraints, contributing to self-determination.

This study examined a grade 9 Natural Sciences teacher’s lessons focusing specifically on how the curriculum imperatives and principles for practical work are being translated in practice. Drawing on data obtained by using ethnographic tools, we describe and discuss an empowerment evaluation approach that will enabled this teacher (i) to reflect upon his understanding of the curriculum design principles for practical work he draws on when planning and teaching science lessons and (ii) to refine and improve how he translates these design principles in advancing an inquiry-based pedagogy.

The research was guided by the following research question: How can an empowerment evaluation approach influence and shift the practice of a Natural Sciences teacher towards an inquiry-based pedagogy?
Research Design and Methodology

A case-study design was used (Merriam, 1998) and qualitative ethnographic methods (Miles & Huberman, 1994) were employed in data collection. Data were collected through classroom observations, a questionnaire and stimulated recall informal discussions. The goal was to empower the teacher in the introduction of an inquiry-based pedagogy informed by the 4Ex2 instruction model, which combines key components of inquiry instruction (Engage, Explore, Explain, Extend) with formative assessment and reflective practice integrated into each of the inquiry components.

The teacher was a BSc graduate in Natural Sciences and held a Post Graduate Certificate in Education (PGCE), majoring in Life Science and Natural Sciences. He was in the second year of teaching. The teacher was purposefully selected for the study, based on his desire to implement and inquiry-based pedagogy. The research site was a school in the North-Eastern province called Gauteng. Shumang Combined School (pseudonym) was located in a semi-rural community. The school offered classes from Grade R to Grade 12, and was classified as a no-fee school due to the low socio-economic status of the community. Most learners came from families who lived in shacks. The school was poorly resourced and did not have a laboratory, however there was a supply of chemical and equipment for experiments that were prescribed by the curriculum.

The researchers applied the Electronic Quality of Inquiry Protocol (EQUIP) as a classroom observation tool when conducting six classroom observations. Using EQUIP, the teacher was assessed on 19 indicators associated with inquiry spreading over four constructs: Instruction (5 items); Curriculum (4 items); Discourse (5 items) and Assessment (5 items). After scoring the teacher on each indicator, a composite score was generated and this could range from 1 to 4 (Level 1 = pre-inquiry, Level 2 = developing inquiry, Level 3 = proficient inquiry, and Level 4 = exemplary inquiry). All lessons were video-recorded and later scored independently by the researchers. The inter-rater reliability (Cohen’s kappa) was computed.
In concert with EQUIP, the Principles of Scientific Inquiry-Teacher (PSI-T) (Campbell, Hashidah, & Chapman, 2010), was employed. The latter questionnaire measures teacher perceptions on the frequency of occurrence of the five principles of scientific inquiry outlined by National Science Education Standards (NSES) (NRC, 1996). These five principles are: (a) Framing research questions; (b) Designing investigations; (c) Conducting investigations; (d) Collecting data; and (e) Drawing conclusions. For each of these principles, 4 items are comprised, and the teacher responded to each item in accord with a 5-point Likert scale that ranged from ‘almost never’ to almost always.’

Stimulated recall discussions enabled the researchers to see the classroom practices through the teacher’s eyes, and to unpack how curriculum design principles were being translated into practice. The discussions centred on the following: the objectives of the lesson, the envisaged learning outcomes, assumptions on which the lessons were based, plan/design of the lessons, and activities during the lessons. We analysed data, looking for evidence in relation to shifts in learner autonomy and changes in the inquiry proficiency level of the teacher.

**Findings**

The findings are presented according to the following stages as encapsulated in the empowerment evaluation approach: stage 1 (stock taking), where the teacher’s grasp of inquiry approach and his perceptions of it were established; stage 2 (setting goals) where at a goal-setting meeting between the teacher and researchers goals were set in order to address the gaps identified at stage 1; stage 3 (developing strategies), and stage 4 (documenting progress) where classroom observations and post-lesson reflection interviews were used to track the progress on the teacher striving towards an inquiry-based pedagogy.
**Stage 1: Stock Taking**

An analysis of the PSI-T questionnaire revealed low scores on framing research questions, designing investigations, conducting investigations and collecting data. This suggested that the teacher perceived his learners had limited opportunity in each of these aspects. An exploratory interview on his PSI-T responses suggested that the teacher was supportive of an inquiry-based pedagogy, but due to his limited experience favoured a teacher-centred approach where he had a tight rein of proceedings. When he did introduce practical work this was mainly in the form of practical demonstrations or ‘cookbook’ type practicals where learners collected data and analysed data by following a worksheet that described a procedure. The first lesson observation served as a baseline to establish the teacher’s current practice in enacting an inquiry-based pedagogy. The inquiry lesson classroom observation tool, EQUIP was employed as a quantitative tool to gauge the extent of inquiry teaching that takes place in a given classroom. The lesson was scored low on all 4 categories of EQUIP, namely instructional factors, discourse factors, assessment factors and curriculum factors. The lesson was heavily dominated by teacher talk that was directed at the dissemination of information on mining and minerals, with little interaction with learners. Based on instruction factors such as instructional strategies, order of instruction, teacher role learner role and knowledge acquisition, the lesson was classified as pre-inquiry, and this placed the teacher as a novice in inquiry teaching and learning.

**Stage 2: Setting Goals**

In the stimulated the recall discussion that followed the first lesson, the teacher recognised the need to shift his practice towards an inquiry-based pedagogy. A goal was collaboratively with the teacher for him to transition to the next level of inquiry, according to EQUIP, namely “Developing inquiry”. The teacher was also made to reflect more clearly on his lesson outcomes, and how his current pedagogy supported these outcomes.
Stage 3: Developing Strategies

In this stage, the instruments used to document progress were discussed. The scoring in the EQUIP observation protocol was explained, and correspondingly the levels of inquiry from pre-inquiry to developing inquiry to proficient inquiry to exemplary inquiry were discussed. The role of the stimulated recall interview was also communicated.

Stage 4: Documenting Progress

The second and third lessons that followed the ‘Setting goals’ meeting, was on acid-base indicators. In the second lesson, the teacher introduced indicators by demonstrating the use of litmus paper and bromothymol blue in testing for acids and bases. The learners asked to take note of the colour of the indicators in the acids and bases. The colour on these indicators in basic and acidic solutions was demonstrated. A stimulated recall discuss after this lesson enabled the teacher to reflected on what learning goals had been achieved, and how the acquired knowledge could be applied. The teacher recognised the need for learners to do become more actively engaged. He planned an investigation based on the use of indicators.

In the third lesson, the learners were given a sample of substances, and asked to classify them into acids and bases. The teacher changed the classroom arrangement and grouped learners. The learners were prompted to write a practical report on their investigation. The report was structured as follows: hypothesis; identifying variables, results, interpretation of results and the conclusion. The scoring of this lesson according to EQUIP showed compared to the baseline lesson changes in certain instructional factors. The role of the teacher from one who demonstrated to evidence of some facilitation. In this lesson the learners were cast from a passive to a more active role. There was also a change in the order of instruction. Whereas in the baseline lesson and second lesson, the teacher explained concepts, in this lesson the learners first did an investigation and this was followed by a
discussion of their results. The scoring of the lesson according to EQUIP showed that the lesson was at the level of proficient inquiry.

In lessons four to six, the teacher demonstrated increased confidence in the implementation of an inquiry-based pedagogy. These lessons remained at the level of proficient inquiry.

Conclusion and Discussion

The current study demonstrated the effectiveness of an empowerment evaluation approach in shifting a teacher’s pedagogical practice from a traditional teacher-centred approach to inquiry-based approach. We commenced with ‘taking stock’ by engaging with the teacher on a discussion on his current practice, and how this practice was not in sync with the learning outcomes he envisaged for his learners. Thereafter, we agreed on the ‘goals’ to be achieved and ‘developed strategies’ in achieving this. We ‘documented progress’ through lesson observations and interviews. This finding reflects the potential of this approach in the supporting in-service teachers through mentoring. It offers a viable and sustained form of professional development that is likely to empower teachers in assessing, planning, implementing and evaluating what they do. The success can be attributed to a stepped approach that is associated with empowerment evaluation (Fetterman, 1999). Another factor that explains the success is the deep reflection done by the teacher in the empowerment evaluation approach that resulted in the teacher making significant changes to his lesson planning and classroom practice. In South Africa, a shortcoming of further teacher education programmes is that these programmes do not engage with the contexts in which teachers work and the level of the existing capacity (Motala, 2003). We maintain that the empowerment evaluation that recognises teaching and learning context is a means by which this shortcoming can be addressed.
References


Relooking Environmental Science Education: The Pedagogical Value of Community-Based Research Projects in Higher Education

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Abstract

We present a community-based research (CBR) model that creates a unique learning environment in higher education through the formation of a tripartite partnership among students, educators and the community to collaboratively engage in research to effect social change. In this case study, a team of undergraduates (n = 3) and educators from the university collaborated with a local high school through the CAPSTONE experience module offered by a residential college at the university. After a needs assessment conducted with the educators at the high school, the undergraduate team developed and implemented an eight-week environmental science education programme that focused on improving the high school students’ knowledge, attitudes and habits towards food waste reduction. This project presented two key benefits. First, the pre- and post-programme quantitative surveys administered to the high school students revealed significant improvement in the attitudes of those who attended the programme (n = 10, 9.1% increase) compared to the control group (n = 19, 0.3% increase). The effects on the students’ knowledge and habits were marginally positive. We inferred that increases in knowledge and changes in habits required sustained interventions over a longer period of time. Second, the project presented pedagogical value for higher education. Through a quantitative eight-point post-project survey (1 = strongly disagree; 8 = strongly agree) adapted from the Association of American Colleges and University (AACU) VALUE rubric, the undergraduates indicated that the project helped them achieve the four learning outcomes: Integrative and applied learning, practical skills, personal and social responsibility, and intellectual skills. The undergraduates’ mean scores on these learning outcomes were consistently high. Collectively, our results accentuated the importance of community-based research projects in supporting environmental science education and holds significant pedagogical value for higher education.

Keywords: Community development, research methods, informal education, collaboration, liberal education
Community-based research (CBR) is a collaborative research approach that engages educators, students and community partners to address a community-identified need (Strand et al. 2003). The engagement of the community partner early in the planning of the project facilitates a deeper understanding of the needs of the client and helps to address the unmet research needs of community-based social service agencies (Anderson 2002). The sustained communication throughout the project allows timely feedback on the research methodologies and encourages collective decision-making (Anderson 2002). This approach also engages diverse segments of the communities in identifying the problem and solutions (Padilla et al. 1999). In terms of pedagogical value for higher education, CBR helps to enhance practical and research skills (Margolis et al. 2000) that facilitates the transition of students to practitioners (Anderson 2002).

CBR differs from conventional research programmes, where researchers are more task-oriented and adopt a supposedly impartial stance (Strand et al. 2003). In CBR, researchers are usually deeply involved with the communities. CBR also distinguishes itself from service learning where students learn through exposure to people with different life experiences and activities without any intention to conduct academic research (Anderson 2002). The ability to meet the academic missions of teaching, research and service has made CBR a functional and revolutionary strategy in higher education (Strand et al. 2003). To date, CBR is widely employed for the social service sectors and clinical work where the focus is on the provision of services to improve the well-being of the community (Strand et al. 2003). However, the application of CBR beyond these disciplines is scant. This is understandably so since the physical sciences tend to focus on investigative lab- or field-based work that do not involve direct contact with human subjects (Hofstein and Lunetta 2004). However, in recent
years, the emergence of interdisciplinary subjects such as Environmental Science has created possibilities for CBR to be applied to these fields. Environmental Science synergizes principles from biology, geography and sociology (Franks et al. 2007). Local communities are often involved in programme development and decision-making (Hindmarsh and Matthews 2008). At present, this field remains largely content-based and environmental messages tend to be nested within academic requirements (Kwan and Stimpson 2003).

In this study, an environmental science education CBR was implemented in the College of Alice & Peter Tan (CAPT), a residential college in the National University of Singapore. The three residential colleges under the University Town College Programme (UTCP) have their unique ethos and they each provide broad-based General Education (GE) programmes that contribute towards the fulfillment of the undergraduates’ degree requirements. CAPT’s ethos of community engagement and active citizenry laid the foundation of CBR through the development of the Capstone experience (CAPSTONE) module. This module has a working model similar to that proposed by Anderson (2002) as it necessitates a close collaboration among the college’s teaching staff, undergraduates and a community partner. In groups of three to five students, the students will address a need identified by the community over the semester (13 weeks). Prior to the commencement of the module, each student group is requested to submit a formal research proposal to outline the background of the issues they are addressing, aims, timeline, methodology for implementation and evaluation of their programme. The formal assessments for this credited module include: 1) situational analysis to link the scholarly underpinnings to the issues identified together with the partner, 2) a final presentation to the college staff, students and community partners to share their work and findings, 3) a final report, 4) a peer and tutor review of the students’ performance and 5) a personal reflection of their learning points throughout the programme.
In 2017, an opportunity arose when a local high school was selected by a government agency to test out a food digester to reduce the food waste in the school. To complement the initiative, the school’s teachers expressed an interest to develop an enrichment programme to bring about behavioral change among selected Grade 8 students (14 year-old students) who are part of the Service Learning Club (SLC), a Co-Curricular Activity (CCA) that focuses on promoting social and environmental awareness among the students. Three CAPT undergraduates conceptualized and implemented an eight-week programme to address this need. The nine lessons in the programme provided content knowledge and imparted practical skills. The high school students were required to make a presentation during a school-wide assembly at the end of the programme. The undergraduate team also incorporated a field trip to promote experiential learning.

In this preliminary study, we examine the impact of the programme on two fronts. First, we evaluated the effectiveness of the programme and its influence on the knowledge, attitudes and habits of the high school students. Second, we examined the pedagogical value of CBR in higher education through the CAPSTONE module.

**Methods**

**Effectiveness of Programme on High School Students**

To assess the effectiveness of the eight-week programme, a pre-programme survey (pre-survey) and a post-programme survey (post-survey) were administered to ten SLC students. Concurrently, an identical set of surveys was also administered to a control group, which comprises another 19 students from the same club who did not attend the programme. The pre- and post- survey questions were identical and examined the students’ knowledge (8 questions), attitudes (18 questions) and habits (9 questions) with regard to food waste management. To evaluate the students’ knowledge on food waste and current management practices, each multiple-choice question had four options with only one correct answer.
(maximum score of 8). To assess the student’s attitudes on food waste management and their readiness to change their behavior, a six-point ordinal scale (1 = “strongly disagree” to 6 = “strongly agree”) was used for each statement (maximum score of 108). To assess the student’s current habits and practices to manage food waste management, a six-point ordinal scale (1 = “never” to 6 = “always”) was used for each statement (maximum score of 54).

To evaluate the reliability of the questions used to assess the attitudes and habits, Cronbach’s alphas were first calculated and a value of more than 0.70 indicated good internal reliability. To test for changes in average percentage scores between the pre- and post-surveys and between the control group and the treatment group, we used a two-tailed t-test of unequal variance at the significance level of 0.05. All statistical calculations were performed using SPSS v21.

Assessing the Pedagogical Value of the CAPSTONE Module on Undergraduate Learning

To evaluate the pedagogical value of the CAPSTONE module, we administered a post-module survey to the three undergraduates. We first aligned the CAPSTONE module learning outcomes to those listed in the Association of American Colleges and University (AACU) VALUE rubrics, a set of goals developed for higher education. The four relevant outcomes were 1) Integrative and applied learning, 2) practical skills, 3) personal and social responsibility and 4) intellectual skills. For each learning outcome, we then selected three variables listed in the VALUE rubric and adapted five corresponding statements for each variable (Table 1). The undergraduates were asked to rank each statement on an eight-point scale (1 = strongly disagree; 8 = strongly agree). The mean score for each learning outcome was calculated by taking the average of the three variables (maximum score of 24; Table 1). In addition, the reflections submitted by the undergraduates were closely read and coded following the same variables used in the survey.
Table 1
Mean score for each of the learning outcome (mean ±SE) and the corresponding variables (mean ±SD) (maximum score = 24)

<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>Mean score ± SE</th>
<th>Variable</th>
<th>Mean score ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical skills</td>
<td>22.9 ± 0.4</td>
<td>Communication</td>
<td>23.2 ± 0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Team work</td>
<td>22.4 ± 0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problem solving</td>
<td>23.2 ± 0.4</td>
</tr>
<tr>
<td>Intellectual skills</td>
<td>20.1 ± 2.5</td>
<td>Inquiry</td>
<td>22.6 ± 1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Critical thinking</td>
<td>21.6 ± 1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Creative thinking</td>
<td>16.2 ± 5.6</td>
</tr>
<tr>
<td>Integrative and applied learning</td>
<td>22.9 ± 0.3</td>
<td>Lifelong learning skills</td>
<td>22.8 ± 0.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global learning</td>
<td>23.2 ± 0.8 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Integrative learning</td>
<td>22.8 ± 0.4 %</td>
</tr>
<tr>
<td>Personal and social responsibility</td>
<td>21.5 ± 1.1</td>
<td>Civic engagement</td>
<td>20.6 ± 3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethical reasoning</td>
<td>21.8 ± 0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intercultural knowledge</td>
<td>22.0 ± 0.7</td>
</tr>
</tbody>
</table>

Results and Discussion

Changes in Knowledge, Attitudes and Habits of High School Students

There was no significant change in the percentage knowledge scores for the control (2.0 ± 0.2%) and treatment groups (0 ±0.2 %). This was likely because the students were already aware of and familiar with the issues before the programme commenced as evidenced by the high percentage knowledge scores (63.1% for control and 67.5% for treatment group).
This was not surprising since the high school has a distinct environmental focus. The school curriculum integrated environmental awareness into their lessons at all levels and provided enrichment programmes to promote an understanding of biodiversity conservation. Furthermore, the SLC students (both in the treatment and control groups) were already active in environmental stewardship and have been organizing environmental programmes. These include public events to raise awareness of waste reduction and the organizing of a nation-wide environmental quiz for local schools.

In contrast, the percentage attitude scores of the high school students in the treatment group increased significantly by 9.1 ± 0.1% (p = 0.002) but not for the control group (0.3 ± 0.03%) and the questions had good internal reliability. The positive outcomes could be due to various factors. The students remarked that the curriculum “inspired them to do more to reduce food waste”. The ownership of showcasing their work to their peers during a school-wide assembly encouraged autonomy, competence and relatedness and thus laid the foundation of attitudinal changes (Deci and Ryan 2008).

The changes in percentage habit scores for the control (7.1 ±0.1%) and treatment group (3.1 ± 0.2%) were not significant. Our results corroborated with the notion that increased environmental knowledge and attitude may not necessarily lead to positive changes in environmental habits (Greaves et al. 2013). Programmes that produced sustained changes in habits are heavily time-dependent and typically require longer duration and more regular interactions with the community (Leeming et al. 1993). As the duration of our intervention was short, it was unlikely to enact visible changes in habits.

**Pedagogical Value of CAPSTONE Module**

The CAPSTONE module was scored very highly (> 20, Table 1) for all four learning outcomes and of these, two outcomes - practical skills, and integrative and applied learning emerged with the highest scores (22.9, Table 1). Since the undergraduates belonged to
different disciplines (Mathematics, Chemistry and Geography), the module created a platform to learn and appreciate different practical skills. For instance, the use of statistical tools in the data analysis was the strength of the Mathematics major and he taught the skills to the other team members. The students highlighted the need to understand and “build on each other’s strengths in a team” (Undergraduate 2) and unanimously acknowledged that teamwork was essential to meet the objectives. As a consequence of the dynamic nature of the project, the undergraduates had to change their plans and to learn to focus on solving the issue. Beyond developing the solutions, they noted that it was equally important to learn how to manage their anxiety and emotions to respond to the problem, especially in light of tight timelines. The undergraduates also appreciated the importance of communication as a practical skill to facilitate the delivery of knowledge and skills to high school students. Peer learning was evident in the programme as the undergraduates were able to pick up communication skills from their team members. What was most significant was the realization that active communication with the partners throughout the engagement was essential in understanding each other’s perspectives and to keep up-to-date with the changes in their plans. One undergraduate noted,

“I came to understand that when working with a community-based partner, communication between the parties and understanding the other party’s perspective is crucial.” Undergraduate 1

While all the undergraduates had prior exposure to environmental science through their formal curriculum in the university and experience in environmental advocacy, the programme required a foundational understanding of pedagogical theories and methods, a discipline that the undergraduates were unfamiliar with. In this process of inquiry, the students found that the consultation with the teaching staff and literature review were essential in structuring their lessons in the programme. They were able to “understand more about pedagogy and ensure that helpful practices are adhered to” (Undergraduate 2). The
objectives and the constraints imposed by the partner also necessitated the undergraduates to think creatively, especially when “multiple unexpected events and developments occurred” (Undergraduate 2). Furthermore, the process of reviewing the literature allowed them to critique what they initially thought was a “convenient and efficient” (Undergraduate 2) approach to delivering the content of the lessons in the programme and to discover the inadequacy of this approach with those suggested in the literature. The programme also prompted the undergraduates to challenge their preconceived notions of education and one of them remarked,

“I have always thought that education is power, but I learnt that power does not always lead to change” Undergraduate 3

The skills and knowledge acquired have made an impact on the undergraduates’ learning. The CBR approach provided the opportunity for them to learn concepts derived from different disciplines. The CAPSTONE module enabled undergraduates to synthesize, apply and evaluate their project and hence promoted integrative learning. They recognized that these skills are crucial to their present work and will continue to benefit them beyond the project. Moreover, the experience also prompted them to think about issues on a broader scale and some had began questioning if educators “should rethink the conventional education model when it comes to environmental stewardship” and to promote teaching in “innovative and refreshing ways” (Undergraduate 2) through collaboration between different parties.

For the undergraduates, this project was their first attempt at engaging and mentoring younger students in a high school. The undergraduates noted they were more aware of their emotions in face of the uncertainty of their engagement, their attitudes towards the high school students and the reactions they received. This in turn, facilitated their understanding of the challenges the high school students’ faced, particularly with the work load (e.g. academic, co-curricular and enrichment activities) and expectation to perform well academically (e.g.
personal, peer and societal pressures). The undergraduates were clearly more emphatic towards the high school students as the programme progressed and grew more conscious of their choice of words. They simplified the content to match the aptitude and interest of the high school students and chose a non-directive approach that instils self-motivation. In addition, they highlighted the importance of protecting the identities of participants in research studies, and appreciated that these studies have to be done professionally and ethically to safeguard the interests of young children. These principles were subsequently woven into their design and implementation of their questionnaires and discussion.

**Conclusion**

The emergence of interdisciplinary subjects such as Environmental Science has facilitated the application of CBR as a pedagogical tool. Through the CAPSTONE module, our results demonstrated that this approach benefitted both the community (i.e., the high school students) and the undergraduate researchers. The eight-week programme implemented in this study was able to improve the attitudes of the high school students towards food waste management. We postulate that the inculcation of environmental values and the focus on experiential and informal learning had a strong influence on this outcome. We believe that with more regular and sustained programmes, the likelihood of behavioral changes can be raised. The CAPSTONE module has also produced positive outcomes in the four selected learning objectives; it was evident that CBR can help prepare undergraduates in expanding their skills beyond the intellectual content. The provision of opportunities in higher education to solve ‘real-world’ problems was a distinct strength of the module.

Beyond environmental science, the CBR model can be readily applied to other interdisciplinary fields such as environmental social work and urban studies. We strongly encourage educators to leverage on CBR as a pedagogical tool in higher education.
Acknowledgements

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References


Promoting Self-Directed Learning (SDL) and Assessment as Learning (AaL) in Science Education in Hong Kong: A Pilot Study in a Hong Kong Secondary School

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Abstract

In this study we address the issue of self-directed learning (SDL) in an EFL Science classroom as a way to provide language scaffold for Hong Kong students who are learners of Science using English as a foreign language (EFL learners). Our central thesis in addressing this question is how to bridge our students from dependent learners to more self-directed learners by gradually releasing learners’ responsibility (GRR) in a language-rich support learning environment. This study thus aims to evaluate the extent of self-directedness in learning by monitoring the learning progress of students.

The study adopts an experimental-based intervention design with two groups of Secondary two (Grade 8) Science students in an English as a medium of instruction (EMI) school in Hong Kong. One average academic ability class was invited as the intervention group while another class stronger in academic ability was invited as the control group. Students in the intervention class received additional language support and SDL elements in the teacher-researcher’s lessons. On the other hand, students in the comparison class received no additional language support. Through the research period, language support used in the intervention group was gradually removed by careful scaffolding in order to increase learners’ responsibility (Fisher and Frey, 2013) and fostered self-directed learning (Grow, 1991) to observe the learning progress of students. Academic achievements of the two groups were measured statistically through formative assessment tasks such as results in uniform tests and examinations. In addition, classroom observations, teachers’ journals, questionnaires were also used to understand the attitudes of the teacher and students towards teaching and learning Science in English during the study. Results, pedagogical and theoretical implications for CLIL and SDL are discussed.
Promoting Self-Directed Learning (SDL) and Assessment as Learning (AaL) in Science Education in Hong Kong: A Pilot Study in a Hong Kong Secondary School

Background

Challenges of Today’s Science Classrooms

Learning and teaching in the 21st century witness great changes in terms of teaching pedagogies, learning environment and learners’ diverse needs. Integration of innovative pedagogical approaches is used to respond to these new social needs. In a typical science classroom in Hong Kong, students with mixed learner diversity are grouped into one classroom. Science teachers often then have to spend great efforts to cater for diverse learning needs: helping students be engaged and motivated to learn science in English-as-the-medium-of-instruction (EMI) environment, teaching students different language, cognitive and generic skills, as well as creating differentiated scaffold, tasks and materials. In particular, for successful and effective learning and teaching of science to take place, science teachers need to create highly challenging yet well supported science-learning activities to scaffold students’ development of science knowledge, academic literacy and cognitive development (P. Gibbons, 2002).

Conducting research studies on science literacy, language across the curriculum (LAC) and content and language integrated learning (CLIL) is crucial for application of innovative pedagogical approaches, particularly in educational contexts where English is not used as a first language like Hong Kong. Many studies concentrated on science learning and teaching while scarce studies focused on scaffolding students to develop science writing skills. Despite the challenging of proving authenticity of works of participants, some studies in science writing could be found. However, the target participants were mostly ENL (i.e. English as a native language) and ESL students but not EFL students (i.e. students do not use English outside of their classrooms) (Wellington and Osborne, 2001). On the other hand,
most science LAC research studies are on vocabulary building level, neglecting the importance of writing texts such as essays as some believe essay writing is not practical to junior form students learning science in Hong Kong. Such negligence could limit Hong Kong students’ development of 21st century skills, which is of utmost importance of their future career and academic advancement.

In this study we address the issue of self-directed learning (SDL) in an EFL Science classroom as a way to provide language scaffold for Hong Kong students who are learners of Science using English as a foreign language (EFL learners). Our central thesis in addressing this question is how to bridge our students from a dependent learner to a self-directed learner by gradually releasing learners’ responsibility (GRR) in a language rich support learning environment. This study thus aims to evaluate the extent of self-directedness in learning by monitoring the learning progress of students.

**Conceptual Framework**

The proposed pilot study is supported by an integrated research-based pedagogical principles derived from different disciplinary studies on supporting students leaning in bilingual educational contexts. These pedagogical principles include: a genre-based approach to teaching academic language across the curriculum (Rothery, 1994/2008; Rose and Martin, 2012; Lin, 2016), metalinguistic and metacognitive awareness raising in assessment task design in academic content subjects and Content and Language Integrated Learning (CLIL) (Lo & Lin, 2014); designing scaffolding for students learning in mainstream English classroom (Gibbons, 2009); self-directed learning (P. Gibbons, 2002, Hew, 2015); assessment as learning (Bow Valley college, 2011).
Literature Review

Self-Directed Learning (SDL)

Knowles’ (1975, cited in Benson, 2011) discussion on self-directed learning provides educators a clearer picture on self-directed learning. Knowles (1975, cited in Benson, 2011) explains that during the self-directed learning process, learners often take the initiative in finding out their learning needs, setting their own learning goals, and identifying relevant resources to achieve these learning goals. Furthermore, the learners choose and apply appropriate learning strategies to achieve their own learning goals as well as to evaluate their own learning outcome for future improvement. It is interesting to note that being a self-directed learner does not necessary mean the learner going through the self-directed process alone and without help – being able to identify one’s needs and locating both human and materials resources is also an important skill in self-directed learning.

A lot of focus is placed on the learners in the discussion of self-directed learning. Alternatively, understanding on self-directed learning can be deepen if teacher-directed learning could also be discussed and compared with. Although both types emphasize the increase in knowledge, skills or personal development of the learners, self-directed learning emphasizes the process is initiated and done by the learner’s own effort while teacher-directed learning is initiated by the teachers (M. Gibbons, 2002). However, this distinction does not imply that self-directed learning and teacher-directed learning are opposites. Gibbons (M. Gibbons, 2002) suggests these two are both important approaches to learning. Instead, it is better to view them as the two ends of one spectrum, allowing both teachers and learners more flexibility for implementing effective learning and teaching. For example, teacher-directed learning is an efficient way to present new ideas, knowledge and practice while self-directed learning is a way to allow students to apply and explore how to make connection between the knowledge and the learners themselves. Therefore, it would be worth
discussing how to transit from teacher-directed learning (TDL) to self-directed learning (SDL) smoothly.

There are different models for explain concepts and elements of self-directed learning. Among all, this pilot study focuses on Hiemstra and Brockett (2012)’s “Person, Process, Context” (PPC) Model as well as Grow (1991)’s SDL model (figure 1 below). The PPC model is an outgrowth of Hiemstra and Brockett’s previous “Personal Responsibility Orientation” (PRO) Model (1991). This updated model can guide teachers to understand how self-directed learning can be most effectively implemented in school settings, focusing on three different important elements: (1) The person or the learner, (2) Teaching-learning transaction or process, and (3) The social context. By analysing these three inter-related elements, teachers can think of ways to gradual release the learning responsibility to students, moving teacher-directed learning to student-directed learning as discuss previously.

*Figure 1.* Hiemstra and Brockett (2012)’s “Person, Process, Context” (PPC) Model.

There are criticisms about lessons with strong support may hinder students’ creativity as the lessons are highly structured. To minimize with this side effect, students are encouraged to take the initiatives to learn – that is the origin of self-directed learning.
However, it is difficult to transform a non-learner to a self-directed learner, especially when the learner is not in well-supported. Therefore, a step-by-step approach is needed to gradually transfer the responsibility to learners (Frey and Fisher, 2013) to promote self-directed learning.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Student</th>
<th>Teacher</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Dependent</td>
<td>Authority Coach</td>
<td>Coaching with immediate feedback. Drill. Informational lecture. Overcoming deficiencies and resistance.</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Interested</td>
<td>Motivator, guide</td>
<td>Inspiring lecture plus guided discussion. Goal-setting and learning strategies.</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Involved</td>
<td>Facilitator</td>
<td>Discussion facilitated by teacher who participates as equal. Seminar. Group projects.</td>
</tr>
<tr>
<td>Stage 4</td>
<td>Self-directed</td>
<td>Consultant, delegator</td>
<td>Internship, dissertation, individual work or self-directed study-group.</td>
</tr>
</tbody>
</table>

*Figure 2. Grow’s Self-Directed Learning model (Grow, 1991).*

**Assessment as Learning (AaL)**

Assessment as Learning (AaL) is also worth exploring in the discussion of self-directed learning. Although Assessment as Learning is an assessment approach which emphasizes students’ being their own assessors, the skills and activities involved in this assessment process is closely related to self-directed learning and can be used to facilitate the self-directed learning process. As a type of formative assessment, assessment as learning is effective in recognizing the gap between what a learner currently knows and what they need
to know (Black and Williams, 1998; Dann, 2013; Sadler, 1989, cited in Dann, 2013). Dann (2002) states that “assessment is not merely an adjunct to teaching and learning but offers a process through which pupil involvement in assessment can feature as part of learning – that is Assessment as Learning (p. 153, cited in Dann, 2013). Dann (2013) further elaborates that assessment as leaning is a “complex interplay of assessment, teaching and learning” (pp. 150-151) and it allows students to understand their own learning progress and goals through applying cognitive skills in a range of activities. Gupta (2016) also suggests that assessment as learning is different from other types of assessment practices and aims to provide opportunity for students to monitor their own learning through self-correction.

These discussions consolidate the connection between assessment as learning and self-directed learning and explain how the two are inter-related. In order to allow students to exercise practice of assessment as learning, portfolios, feedback, peer-assessment and self-assessment are some common examples used by educators (Everhard, 2015). These learning activities allow students to move from summative assessment practice to formative assessment practice, from teacher-centred to student-centred learning process (Everhard, 2015). The use of assessment as learning practice also allows students to move away from learning that “perpetuates dependence” on the teachers and be able to acquire learner autonomy and skills that allow them to endure and sustain lifelong learning (Everhard, 2015).

**Content and Language Integrated learning (CLIL)**

Content and Language Integrated Learning is an umbrella term adopted by researchers and the European Network of Administrators, Researchers and Practitioners (EUROCLIC) in the mid-1990s (Coyle,1999) in discussion related to content-based instruction (CBI), immersion classes, bilingual education. The main focus of Content and Language Integrated Learning (CLIL) is its strong emphasizes on providing students with support on both content and language focuses.
There are four dimensions in the CLIL model, namely content, communication, cognition and culture. Content in the model refers the subject knowledge while communication means how to communicate in English and how to communicate science in English. This model is welcomed by researchers and educators as it involves high order thinking skills in cognition and can be easily integrated with other approaches, such as Science, Technology, Engineering and Mathematics (STEM) approach and Science, Technology, Society and environment (STSE) education as the culture of the one of the 4Cs.

![CLIL Model Diagram](image)

*Figure 3. The CLIL model (adopted from Coyle, 1999).*

**Research Gap**

The above discussion of self-directed learning, assessment as learning, as well as CLIL and science education indicates one important question: How to help students to transit from Teacher-Directed Learning (TDL) to Self-Directed Learning (SDL) smoothly when they are learning to do science experiments in an EMI environment? Although self-directed learning has been widely implemented post-secondary and across many fields at college level, few studies look into self-directed in learning in science practical skills from secondary school contexts.
Research Methodology

Research Design

Action research is used as the research design of this study. Action research is appealing to teacher researchers is that it allows teachers themselves to have self-reflective teaching in order to enhance their teaching effectiveness. Moreover, most action research can be naturalistic which does not produce many perturbations to normal teaching.

Research Design and Participants

Participants were drawn from 2 classes in secondary 2 studying Junior Form Integrated Science in a Band 1 secondary school in Hong Kong with one class (2E) being a treatment group with incidental SDL activities and another class (2A) being a control group received conventional teaching with the same academic ability and gender mix.

Methods of Data Collection

Questionnaires. A structured questionnaire with ranking questions using 5-point Likert scale was employed in order to collect students’ opinion on science teaching and learning, content and language integrated approach and self-directed learning. Ranking questions were used to measure students’ degree of satisfaction and agreement to different teaching activities. The means of the questionnaire data would be compared.

Focus group interview questions. In addition to the questionnaire, a semi-structured focus group interview were used to collect more in-depth and open-ended responses from the students. A set of interview questions was discussed between the researchers before the interviews. The aim of the focus group interviews is to allow the researchers to ask more qualitative questions to collect students’ opinions in addition to the questionnaires.

Tests. The content of students’ test papers throughout the period of study was analysed for both content and language awareness of students in order to give an answer to
another research question – whether students’ content and language awareness change after intervention.

**Findings**

**Questionnaires**

Comparing with the questionnaire data before and after the study period, students did not have a significant change in attitude towards science teaching and learning. However, students had a significantly positive change in attitudes toward content and language integrated learning, especially they were confident in using subject-specific vocabulary in science, describing observations and construct different types of texts in science. Nevertheless, students were not so positive in self-directed learning. After the intervention, students were not so clear about how to choose appropriate materials for learning. These suggest that students did not have a significant in attitude on core science teaching and learning. Although they welcomed CLIL approach they are hesitant towards SDL approach.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am confident in my ability to learn content subject knowledge (e.g. history, mathematics) in English.</td>
<td>3.43</td>
<td>3.71</td>
</tr>
<tr>
<td>I like learning science through science lessons.</td>
<td>3.71</td>
<td>3.71</td>
</tr>
<tr>
<td>I like learning science on my own.</td>
<td>3.16</td>
<td>3.19</td>
</tr>
</tbody>
</table>

*Figure 4.* Attitudes towards science teaching and learning.
<table>
<thead>
<tr>
<th>Statement</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am confident that I can use scientific vocabulary when I learn science in English.</td>
<td>2.97</td>
<td>3.24</td>
</tr>
<tr>
<td>I can construct different sentences when I learn science in English.</td>
<td>3.13</td>
<td>3.04</td>
</tr>
<tr>
<td>I can construct different types of texts when I learn science in English.</td>
<td>2.86</td>
<td>3.14</td>
</tr>
<tr>
<td>I can describe observations when I learn science in English.</td>
<td>2.94</td>
<td>4.61</td>
</tr>
<tr>
<td>I can design different scientific experiments when I learn science in English.</td>
<td>2.75</td>
<td>2.90</td>
</tr>
</tbody>
</table>

**Figure 5.** Attitudes towards CLIL.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am confident that I can use scientific vocabulary when I learn science in English.</td>
<td>2.97</td>
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</tr>
<tr>
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</tr>
<tr>
<td>I can design different scientific experiments when I learn science in English.</td>
<td>2.75</td>
<td>2.90</td>
</tr>
</tbody>
</table>

**Figure 6.** Attitudes towards self-directed learning.

**Teacher Observations**

Although it was reported that students were not quite welcome SDL approach, their performance showed some SDL elements. With more freedom released in the lessons, students were willing to try out more out of the experimental manual. Apart from teaching and learning objectives set by the teacher, students were more willing to set some extra goals to achieve more in experimental sessions. For example, students were asked to complete a circuit by using 2 cells and one light bulb. Middle and low achievers finished it and set additional meaningful goals, such as constructing circuits to make more light bulbs lighting
up. Another example is that students were asked to test the pH value of liquids. Some middle achievers tested the pH value of wastewater of this experiment driven by their curiosity. Although literally students did not know too much about the direction of SDL approach, they are doing practical work with SDL elements.

**Students’ Work**

Students’ works showed the effectiveness of learning through CLIL approach. The script produced by high achievers before the intervention contained some careless spelling mistakes but their writing were error-free after the intervention. For middle achievers, they used to write subject-specific words in point form as answers before the intervention. After the intervention, they managed to write in complete sentences, despite there were some spelling mistakes in the answers. For lower achievers, before the intervention they left blanks for difficult questions and tried to guess for short answers. After the study, they tried to write complete sentences with incomplete ideas. For instance, they wrote ‘gas bubbles’ instead of ‘colourless gas bubbles’. After this intervention, it shows that CLIL approach helps students, particularly with middle achievers and low achievers.

**Focus Group Interviews**

Focus group interviews show students’ perception in science learning. In the pre-interview, most students expressed they love doing science experiments. Some high achievers even read science book to enrich their science knowledge. However, most students commented that they failed to write something accurate, such as writing observations or conclusions. Moreover, some low achievers reckoned that although scientific investigations are interesting to do, learning science involves a lot of memorization, which is further challenged by learning science in English. They hoped to have more language support for learning science. To cope with these challenges, students preferred writing summary or doing
exercises as consolidation. This interview is useful in knowing the needs of the students in order to tailor made teaching and learning activities for them.

After the intervention, they commented in the post-interview that the ‘new’ teaching method helps their summative assessments, monitoring time management and learning practical skills. Nevertheless, students did not know the main focus of the peer assessment due to unclear and wordy instructions. When coming to evaluate the suitability between the new teaching method and conventional teaching method, high achievers welcomed conventional teaching method as they loved the synergy of group work while middle and low achievers welcome new teaching method as new teaching method increased students’ autonomy. They could have more time to try and explore the experiments.

**Discussion**

**Why SDL and AaL cannot be Implemented Smoothly**

Students in the treatment group were generally unaware that they were learning science through SDL during the intervention. The reason is that the teacher did not explicitly give out instructions with emphasis of SDL. Instead, the teacher just imply without great emphasis. According to the PPC model (Hiemstra and Brockett, 2012), the inexplicit instructions by the teacher cannot create a positive atmosphere to SDL, and communication breakdown between the teacher and students cannot provide a smooth and effective teaching and learning process. Therefore, SDL was not promoted very successfully in this study. Furthermore, students were not aware of the feedback generated throughout teaching and learning activities and they were not aware that they need to make effort to become a self-directed learner. Instead, they were assessed by the teacher and the teacher gave out feedback deliberately. Consequently, assessment as learning was not implemented smoothly but students and teacher interacted well in terms of assessment for learning.
Why Students Welcome CLIL

Students in the treatment group generally welcomed CLIL approach as it provides rich language support to tackle formative assessment questions when learning science. Moreover, the teaching package in this study highly resembles the CLIL model suggested by Coyle (2008) – it has covered essential content knowledge in acids, alkalis and electricity, writing observations for reactions and describing relationships between current and voltage have been highly emphasized to ensure effective communication of science knowledge and trial and error approach has been adopted to foster problem solving skills in science. However, high order thinking strategies were not emphasized too much. Therefore, students thought that CLIL approach was useful in helping them securing a passing score but not a high score.

Conclusion

In this study, teacher-directed learning was not transited smoothly to self-directed learning due to the lack of readiness of teachers and students. Moreover, assessment as learning was not promoted effectively because of the time constraint. Despite of this, middle and low achievers benefits from the CLIL approach with strong language support in order to cope with their learning difficulties. If these pedagogical elements are to be implemented again, sufficient time and explicit instructions are needed to cultivate a favourable learning environment with collaboration between teachers and students.

Acknowledgement

We would like to thank our advisor Professor Angel Lin Mei-yi of the Division of English Language Education at the University of Hong Kong. The door to Professor Lin’s office was always open whenever we ran into a trouble spot or had a question about our research or
writing. She consistently allowed this paper to be our own work, but steered our in the right
direction whenever she thought we needed it.
References

https://doi.org/10.3102/0013189X11428813


Nurturing Scientific Literacy for All Undergraduates via Science Classics

Kiang Kai Ming, Cheung Hang Cheong Derek and Ng Ka Leung Andy

Office of University General Education, The Chinese University of Hong Kong
Abstract

It is often a challenge to design a curriculum that aims to nurture scientific literacy for every type of students. On one hand, non-science students would find the quantitative aspects of science very difficult to grasp. On the other hand, teaching only the qualitative aspects of the nature of science may not necessarily be appealing to the science students. In this paper, we suggest that reading science classics can be a suitable means for putting different kinds of students together in a compulsory course that aims to nurture scientific literacy for several reasons. First, science classics encompass enduring questions that are common to all human beings of various disciplines and backgrounds. Second, science classics provide opportunities for the students to explore the relationship between science and the livings, cultures and religions of the society. Third, reading science classics develop an awareness of great people and great ideas, which is in itself a strong enough reason to demand those students having no interest in science to participate. Fourth, using primary literature has unique potential to instruct students on the nature of scientific reasoning and communication. The performance of the students who studied the course In Dialogue with Nature, which is offered by the Chinese University of Hong Kong, is studied. This course is a compulsory course that aims to nurture scientific literacy for all students, including both science and non-science students. The performance is evaluated by the entry and exit surveys as well as the academic grades of the students. The result is that both the science and non-science students have gained significantly in all the factors related to the intended learning outcomes of the course. This seems to support the view that cultivating scientific literacy in higher education setting can be achieved via the classics reading approach.

Keywords: Classics, Scientific Literacy, General Education, Higher education, Multidiscipline.
Nurturing Scientific Literacy for All Undergraduates via Science Classics

Nurturing scientific literacy has been one of the focuses in educational reform in the recent decades (OECD 2007, 2016). While scientific literacy has various definitions, there are two important aspects: one is on the understanding of the science and technology enterprise and its relationship with the public (DeBoer 2000, Roberts 2007); another is to develop generic skills and knowledge, such as critical thinking skills and self-learning skills (Norris & Phillip 2003; Hurd 2000). To attain this goal, many new curriculums for science education were designed and implemented at different levels of education worldwide (Hurd 1998, Fairweather 2010). This is related to a belief that “science is a subject suitable and necessary for all learners, which should be a core and sacrosanct part of the curriculum.” (Taber 2014). However, in order to be suitable for all kinds of student, these courses must be less technical and less mathematical so that the least scientific oriented students can still be benefited. This means that if the science education course is to be compulsory, then it needs to be more focusing on the qualitative aspects of science.

For this reason, some would argue that this approach of teaching science is not an authentic science education as it cannot demonstrate the quantitative, rigorous, and objective aspects of science (Taber 2007). They would even argue that rather than fruitlessly trying to provide science education to those that are not capable, resources should be spent on those students that have the talents so that they can be better equipped in their future scientific career. The debate between ‘science for all’ or ‘science education for the good of all’ rooted therefore on the fact that whether there is really a practical and authentic science education that is suitable for the general population.

Reading Science Classics

In this paper, we suggest that for higher education, one practical way of cultivating scientific literacy qualitatively could be via reading science classics. Reading classics as a
tradition has its root traced to the beginning of universities during the medieval (Lindberg 2007). This tradition is maintained in many well-established colleges that are using the classics reading approach for liberal education, such as the St. John’s College (2018) and Columbia University (2018). Among the various types of classics, science classics are, according to Gjertsen’s (1984) definition, “ones which transform science, or, in more fashionable language, which produce a major intellectual revolution”. The advantages of letting university students to read science classics are, first, science classics encompass enduring questions that are common to every human being and hence can be related to all students of various disciplines and backgrounds (Carson 1997; Goodney and Long 2003). Second, science classics are part of the history of the development of civilizations that impacted the livings, cultures and religions of the society, which provides opportunities for the students to explore the relationship between science and these areas. This is especially important when it is related to the similar questions raised by students’ daily life when they encountered impacts brought by advances at the frontiers of modern science and technology (Movahedzadeh 2011). Third, reading science classics at its very least develop an awareness of great people and great ideas, which allow the students “following the footsteps of great minds” (Chan, Szeto, and Wong 2012). This is in itself a strong enough reason to demand those students having no interest in the qualitative aspects of science to participate. Fourth, as Muench (2000) has pointed out, “The value and appeal of using primary literature in the classroom are rooted in literature’s unique potential to instruct students on the nature of scientific reasoning and communication”.

**A Science Classics Reading Course – In Dialogue with Nature**

The Chinese University of Hong Kong (CUHK) introduced the General Education Foundation (GEF) Programme specially designed for the four-year curriculum in 2010 (OUGE 2011). Beginning from 2012, it became compulsory for all approximately 4000
students intake per year. One of the GEF course is called In Dialogue with Nature (abbreviated as the course code UGFN in the following), which requires students to read science-related classic texts. Through reading these classic texts, students will discuss and reflect on the core questions brought up by the classics and how they are related to modern issues.

The selected readings for UGFN are excerpts of the texts listed in Table 1. These excerpts are compiled into the textbook of this course (Chan, Szeto, and Wong 2012). The list comprises texts which are related to ancient Greek philosophies, ancient Chinese science and modern science. These are divided into three parts to address three main enquiries of human on Nature: Part I is about the human exploration of the physical universe; Part II is about the human exploration of the world of life; and Part III is about our understanding of human understanding itself.

Table 1

Lists of readings for In Dialogue with Nature (UGFN) since 2012

<table>
<thead>
<tr>
<th>Part I: Human Exploration of the Physical Universe</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Republic / Plato</td>
<td></td>
</tr>
<tr>
<td>The Beginnings of Western Science / David C. Lindberg</td>
<td></td>
</tr>
<tr>
<td>The Birth of a New Physics / I. Bernard Cohen</td>
<td></td>
</tr>
<tr>
<td>The Principia: Mathematical Principles of Natural Philosophy / Isaac Newton</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part II: Human Exploration of the World of Life</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>On The Origin of Species / Charles Darwin</td>
<td></td>
</tr>
<tr>
<td>DNA: The Secret of Life / James D. Watson</td>
<td></td>
</tr>
<tr>
<td>Silent Spring / Rachel Carson</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part III: Our Understanding of Human Understanding</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Science and Method / Henri Poincaré</td>
<td></td>
</tr>
<tr>
<td>In Search of Memory: The Emergence of a New Science of Mind / Eric R. Kandel</td>
<td></td>
</tr>
<tr>
<td>The Shorter Science and Civilisation in China / Joseph Needham</td>
<td></td>
</tr>
<tr>
<td>Why the Scientific Revolution Did Not Take Place in China — or Didn't It? / Nathan Sivin</td>
<td></td>
</tr>
<tr>
<td>Brush Talks from Dream Brook / Shen Kua</td>
<td></td>
</tr>
<tr>
<td>The Mathematical Universe / William Dunham</td>
<td></td>
</tr>
<tr>
<td>Elements / Euclid</td>
<td></td>
</tr>
</tbody>
</table>
As the aim of this course is more related to the reflection on the revolutionary thoughts towards nature from the great thinkers under historical and cultural contexts, instead of teaching any particular scientific knowledge, it was anticipated that it is suitable for all undergraduate students to take this course regardless of their previous science education. Through reading the original texts, this course also provides an opportunity for students to develop their critical thinking skills and to assess their own meaning of life and other value-related issues.

To enhance the effectiveness of the course, discussion-based tutorial and teachers’ preparedness in the science classics are the main key ingredients of this course (Martin 2010, Odom, Stoddard, and LaNasa 2007). The weekly structure of the course consists of a two-hour student-oriented tutorial and a one-hour lecture. Each tutorial class would usually consist of a maximum of 25 students with well-mixed academic backgrounds. This is deemed a constructive atmosphere for students to exchange ideas across disciplines.

**Evaluation Methodology**

The GEF Programme as a whole has been assessed by an external reviewer, Jerry Gaff, Senior Scholar of Association of American Colleges and Universities, in 2014. In his formative evaluation report (Gaff 2014), it is noted that “there is considerable evidence from students and teachers alike that students are achieving important learning outcomes; enhanced reading ability and critical analysis, confidence in confronting difficult texts, open-mindedness and appreciation for intellectual diversity, and self-discovery of their own interests, abilities, and tastes.” Association for General and Liberal Studies (AGLS) also recognized the GEF Programme with an award for Exemplary International General Education Program Improvement in 2015. The awards assessment criteria can be found in (Nichols, Mauldin, and Gaff 2015).
To further evaluate the course with quantitative evidence, we adopted the IEO model as our framework of assessment (Astin 2012). The IEO model is suggested by Alexander Astin that “any educational assessment project is incomplete unless it includes data on student inputs, student outcomes, and the educational environment to which the student is exposed. Outcomes, of course, refer to the “talents” we are trying to develop in our educational program; inputs refer to those personal qualities the student brings initially to the educational program (including the student’s initial level of developed talent at the time of entry); and the environment refers to the student’s actual experiences during the educational program.”

In line with the IEO model, two student surveys, namely entry and exit surveys, were designed and conducted at term start and term end. This survey design allows us to measure the status of students at two different time points. Generally, the two surveys were conducted during the first and the last lesson of the participating classes. For practical reasons, some classes conducted the exit survey during the second last lesson due to the different class arrangement by different lecturers. The data gathered in the entry survey can act as a defined baseline while the data gathered in the exit survey can be considered as the final outcome. The surveys were designed to look into students’ backgrounds, their effort spent on the course, their self-perceived achievements in the ILOs and their views toward the effectiveness of various learning methods. Moreover, there are 17 questionnaire items which are repeated in the two surveys allowing us to track students’ performance changes. The validity of using entry-exit surveys to measure student’s perception was reported in (Ng, Kiang and Cheung 2016). The surveys were also used in other related analysis (Kiang, Ng and Cheung 2015 and Kiang et. al. 2016).
Data Collection

The surveys were given by the lecturers to the students who were voluntarily participating. The surveys requested the students to fill in the last five digits of their student ID numbers to uniquely identify each student so that additional information related to the students could be retrieved. This information was acquired with the consent of the student volunteers with a guarantee of having no consequences to their academic grade.

In the academic year of 2015-2016, 15 course lecturers helped to distribute the entry and exit surveys in all or some of their tutorials. In total, there were 114 tutorials surveyed during the academic year of 2015/16. 60 tutorials were from Term 1, 50 tutorials were from Term 2, and 4 tutorials were from the Summer Term. 81 tutorials were taught in Cantonese, 16 tutorials were taught in Putonghua and 13 tutorials were taught in English. There are 2518 students enrolled in these 114 tutorials at the end. 2311 students participated in the entry survey and 2146 students participated in the exit survey. The discrepancy in the number of participation was mainly due to students’ absence in the first or last tutorial sessions or late add-drop from the classes. Among all participated students, a total of 1823 was successfully tracked from the entry and exit surveys. The tracking rate is 78.89%. Some students were tracked unsuccessfully because they completed only one of the two surveys or because they did not provide sufficient information for tracking. Analysis in this report is derived from the data of these successfully tracked students.

Additional student information was retrieved from the university database, the Chinese University Student Information System (CUSIS). Data collected from this source includes students’ affiliated faculty, year of study, cumulative Grade Point Average (cGPA), term GPA, UGFN Grade and affiliated college. Moreover, information about the tutorial classes, for instance, medium of instruction, tutorials location, tutorial time and tutorial size was also collected from CUSIS.
Survey Factors

The 17 survey items could be further classified by using factor analysis. This statistical technique allows one to see the hidden structure of the survey items as derived from the data collected. It can also reduce the number of dimensions so that human readers can more easily comprehend the data to generate more useful information from it. The factor analysis was conducted using R and we followed the procedures as reported in (Field, Miles, and Field 2012), which involves the use of Principal Component Analysis with “oblimin” factor rotations (Pedhazur and Schmelkin 1991). This resulted to 5 factors with each representing a group of survey items as listed in Table 2. For each of the factors, Cronbach alpha (1951) were calculated to ensure the reliability of the factor. As the alphas are all $> .7$, this falls within the range of acceptable reliability suggested by Kline (1999).

Table 2

The Survey Factors and its comprising items

<table>
<thead>
<tr>
<th>Name of the Factor</th>
<th>Comprising survey items</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Logical Thinking and Communication Skills</td>
<td>1, 3, 4, 5</td>
<td>0.73</td>
</tr>
<tr>
<td>2: Appreciation of Science</td>
<td>6, 7, 8</td>
<td>0.85</td>
</tr>
<tr>
<td>3: Understanding of Science</td>
<td>9, 10, 11, 12</td>
<td>0.88</td>
</tr>
<tr>
<td>4: Understanding of Good Life and Good Society</td>
<td>13, 15</td>
<td>0.76</td>
</tr>
<tr>
<td>5: Appreciation of Diversity</td>
<td>2, 14, 16, 17</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Academic Performance as the 6th Factor

To obtain an objective measure of students’ performance, we retrieved also two representative academic grades for each student in the following analysis. First, the cumulative Grade Point Average (GPA) before a student study the UGFN is obtained. We considered this to be a measure of the students’ entry academic performance, similar to that
of the Entry survey. Second, the course grade the student obtained at the end of studying UGFN is considered to be a measure of the students’ exit academic performance, similar to that of the Exit survey. This pair of grade is then considered as the 6th factor in the following analysis, together with the 5 survey factors.

**Results**

The five mean survey factor ratings in Entry and Exit Survey, and the changes of survey factor rating, along with the difference of academic performance in cGPA before and UGFN GPA were presented in Table 3 and 4 as well as in the form of a radar diagram as shown in Figure 1. Note that the scale of academic performance was standardized in this Figure to that of the other survey factors for a fairer and symmetrical illustration (from a normal grade point range of 0 to 4 into 1 to 6).

Table 3

*Mean Ratings of the Factors*

<table>
<thead>
<tr>
<th>Name of the factor</th>
<th>Before</th>
<th>After</th>
<th>Change</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical Thinking and Communication Skills</td>
<td>4.03</td>
<td>4.44</td>
<td>0.41</td>
<td>5.59E-117*</td>
</tr>
<tr>
<td>Appreciation of Science</td>
<td>4.29</td>
<td>4.62</td>
<td>0.33</td>
<td>1.97E-57*</td>
</tr>
<tr>
<td>Understanding of Science</td>
<td>3.72</td>
<td>4.64</td>
<td>0.92</td>
<td>4.20E-279*</td>
</tr>
<tr>
<td>Understanding of Good Life and Good Society</td>
<td>3.98</td>
<td>4.61</td>
<td>0.63</td>
<td>1.95E-158*</td>
</tr>
<tr>
<td>Appreciation of Diversity</td>
<td>4.63</td>
<td>4.93</td>
<td>0.30</td>
<td>1.17E-66*</td>
</tr>
<tr>
<td>Academic Performance</td>
<td>3.12</td>
<td>3.21</td>
<td>0.09</td>
<td>1.38E-13*</td>
</tr>
</tbody>
</table>

*Note: *indicates statistical significance in two-tailed paired t-test at p<0.05.*
Table 4

Counts of Different Changes of the Factors

<table>
<thead>
<tr>
<th>Name of the factor</th>
<th>Down</th>
<th>Flat</th>
<th>Up</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical Thinking and Communication Skills</td>
<td>346</td>
<td>255</td>
<td>1209</td>
<td>6.30E-106#</td>
</tr>
<tr>
<td>Appreciation of Science</td>
<td>460</td>
<td>329</td>
<td>1019</td>
<td>1.06E-47#</td>
</tr>
<tr>
<td>Understanding of Science</td>
<td>166</td>
<td>163</td>
<td>1473</td>
<td>2.61E-228#</td>
</tr>
<tr>
<td>Understanding of Good Life and Good Society</td>
<td>254</td>
<td>367</td>
<td>1178</td>
<td>2.13E-131#</td>
</tr>
<tr>
<td>Appreciation of Diversity</td>
<td>408</td>
<td>313</td>
<td>1060</td>
<td>9.58E-65#</td>
</tr>
<tr>
<td>Academic Performance</td>
<td>605</td>
<td>9</td>
<td>852</td>
<td>1.58E-10#</td>
</tr>
</tbody>
</table>

Note: # indicates statistical significance in two-tailed paired sign test at $p<0.05$. 
Figure 1. The performance of the students in UGFN before, after, and the net change, *indicates statistical significance in two-tailed paired t-test at p<0.05, #indicates statistical significance in two-tailed paired sign test at p<0.05.
The data were then put into two types of statistical test. Two-tailed paired t-test was and Two-tailed paired sign test. In the former, the survey ratings were treated as interval scale; the latter, the ratings were only treated as ordinal scale and the changes of rating were categorized as Down, Flat and Up depending on whether individual student experienced negative change, no change or positive change instead of calculating their numerical differences. This can eliminate some reported concerns of the use of mean score on Likert-scale survey data (Jamieson 2004, Allen & Seaman 2007). Moreover, treating the survey data as scores would be more influenced by students having larger effects, whereas treating it as changing directions would measure the percentage of students that attains the intended outcome, regardless of the magnitude of the individual’s effect. It should be noted that, however, such simplification of data can also be considered as a drawback which lost information about the magnitude of effects per student (MacCallum et al. 2002). The two ways of analysis are hence complementary to each other to provide a more comprehensive view on the effects of the micro-modules. In another words, the former method measures the average effect per student and hence could be described as measuring the depth of effects, whereas the latter method measures the percentage of students having effects and hence could be described as measuring the width of effects.

For all the factors, there were statistically significant positive changes from before to after in the two types of statistical tests. This means that during the study of UGFN, students experienced significant improvement in their perception on all the factors that are related to the course ILOs, which are ultimately, related to nurturing scientific literacy. While there could still be other uncontrolled factors that could influence the students in this change (Schunk & Meece, 1992; Dochy et al., 1999), the most possible cause is arguably due to the success of the course.

Moreover, the changes in the two factors related to the cognitive domain (Understanding of Science and Understanding of Good Life and Good Society) were much
larger than the other two factors which are more related to the affective domain (Appreciation of Science and Appreciation of Diversity). The factor on Logical Thinking and Communication Skills is in between these two categories. This result matches educational literature that students tend to learn easier in the cognitive domain than in the affective domain (Bloom et al., 1956 & Krathwohl, 1973).

Besides raising students’ understanding and appreciation of science, this course is also effective in raising the other factors, including logical thinking and communication skills, appreciation of diversity and the understanding of good life and good society. The ability in these factors is also related to the broad sense of scientific literacy as discussed in the introduction.

In essence, the course has been effective in nurturing scientific literacy for all kinds of university students as a whole.

Conclusions

We suggested that reading science classics can be an effective way to nurture scientific literacy at higher education level. As a compulsory course for the Chinese University of Hong Kong, In Dialogue with Nature requires students to read science-related classics. Our study shows that it has an effect of raising students interest and confidence in their understanding of science. Furthermore, the course also increases all students’ logical thinking and communication skills, appreciation of diversity and the understanding of good life and good society, which can be considered to be indirectly related to and foundation of one’s scientific literacy.

Future studies need to investigate what other factors might contribute to the success of this course and the importance of each of them. Another research direction is to devise methods to compare the effectiveness of classics reading on nurturing scientific literacy with the traditional pedagogies.
Acknowledgements

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References


*Taxonomy of educational objectives: The classification of educational goals.


The Factors of Pre-service Teacher Training Process to Create Active Learning in Teaching Science: Case Study the Pre-service Science Teachers in Thailand

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Abstract

The aim of this study was to find the factors of pre-service teachers training process to create active learning professionally in teaching science in Thai context. We used a case-study research and selected four pre-service teachers to be case study. The data was collected by documents analysis, classroom observations and semi-structure interview. Then, the data was analyzed and interpreted based on characteristics of active learning and used the triangulation to control the quality of this study. The results showed that four pre-service science teachers provided the students to observe, discus and analyze scientific contents before their answers the question. Furthermore, they encouraged the students to do activities with interpretation collaboration work, barnstorming in within group and self-learning in doing the activities. Some of them taught students to do experiment and provided students to do experiment by themselves. Moreover, in the end of teaching and learning in science classroom, all of pre-service science teachers encouraged the students to present the outcomes of their learning to their classmate. We found that the teaching of four pre-service teachers related to characteristics of active learning which are: 1) students are participated in the learning more than listening, 2) students are developed skills by doing by themselves, 3) students are involved in higher order thinking, 4) students are engaged with learning activities and 5) students are explored with their attitudes and values (Bonwell & Eison, 1991). In addition, the semi-structure interviews results from four pre-service teachers and their supervising teachers showed that there were four factors of effectiveness processes to train pre-service teacher as following:

- Observation: observe their friends’ class
- Question: practice in constructing the questions to ask students interactively
- Discussion: create lesson plan with discussion group
- Refection: receive the feedback after their teaching

Keywords: active learning, pre-service teacher, training teacher
The Factors of Pre-service Teacher Training Process to Create Active Learning in Teaching Science: Case Study the Pre-service Science Teachers in Thailand

Teaching science is one of instruction that require students to take an active part in learning (Moustafa & Zvi-Assaraf, 2013). In active learning, teachers need to encourage students to participate in doing activity which force them to think about what they are doing (Bonwell & Eison, 1991, p. 19). In addition, teaching should support students to collaborate in learning that provide them to interact with classmate and their teachers (Michaek, 2006; Akinoglu & Tandoğan 2007; Bakir 2011; Derevenskaia, 2014). The general of students’ learning in science classroom depend on teaching activity of their teachers. Actually, teacher centre of teaching style is easy for made it happen in class but it be trouble for students in learning. It is very important to embed in mine of in-service teachers to construct actively activity in class, since they were pre-service teacher. Pre-service teachers were students that studying in the 5th year of study and they have to practice in school for one year, which they need to create teaching and learning for their teaching. Consequently, the training processes for creating active learning in teaching science are play an important role for pre-service science teachers need to be trained. Petersen and Olson refer the way of good teaching that teachers are active observations continuously gathering information about their students. Teachers need to see students working in small group and listen to student comments during small group to determine how students are applying science concepts. Furthermore, teachers must use questions in teaching and do the questions on different levels for students learning (Moustafa & Zvi-Assaraf, 2013; Eshach, Ziderman & Yefroimsky, 2014; Vickery, 2014 p. 20). In addition, Abell and Bryan suggested that, teachers could be reflected in their teaching (Abell & Bryan, 1997) because reflection involve monitoring what happens in the process of teaching and learning (Vickery, 2014). Therefore, if pre-service teachers perform in these ways. It made them improve in their teaching because they can share classroom experiences
with others for feedback about their teaching, evaluate whether their teaching matches theoretical view of teaching and learning, and raise the question to use in their teaching (Faikhamta & Clarke, 2013).

In Thailand, pre-service science teachers can not improve ability to develop in lesson planning techniques, teaching strategies, student learning processes and incorporation of instructional material (Faikhamta, Jantarakantee & Roadrangka, 2011). Moreover, many pre-service teachers still used traditional teaching such as lecture and inability to create scientific activity. For this reason, construction of teaching and learning were play an important role for pre-service science need to be trained. Therefore, the aim of this study was to find the factors of pre-service teachers training process to create active learning professionally in teaching science.

**Methodology**

This study employed a qualitative method with a case-study research (Creswell, 2003, p. 24) to find the factors of pre-service teachers training process to create active learning professionally in teaching science in Thai context. The research site was four pre-service science teachers (PSTs) to be case study by selecting from their performance in micro-teaching since they were studying in the 4th year of study. There were two groups of them, one was a group of good performance (Group A) and another one was not good performance (Group B). When they were pre-service science teachers, studying in the 5th year of study, they have to practice in school for one year. In addition, we used three instruments consisting of; 1) document in lesson plans, 2) observation form and 3) interview form to collect data.

**Data Collection**

In the practicum year of four pre-service teachers, they were observed by the researchers. Three lesson plans of four PSTs were investigated and observed in teaching
science for three time in order to know how they teach by using active learning criteria (Bonwell & Eison, 1991, p. 19). Then, we interviewed four PSTs and their supervisor teachers in order to find the factors to support pre-service science teachers teaching.

**Data Analysis**

Data from lesson plans and classroom observation were analyzed by using criterion of characteristics of active learning (Table 1). The data of interviews, we analyzed by grouping the same words and categorized. Then, interpreted to separate the factors of PSTs training process. In addition, we used the triangulation to control the quality in this study.

Table 1

*The characteristics of active learning (Bonwell & Eison, 1991, p. 19)*

- Students are involved in more than listening (interaction and collaboration)
- Less emphasis is placed on transmitting information and more on development of students’ skills (doing by themselves)
- Students are involved in higher order thinking (analysis, synthesis, evaluation)
- Students are engaged in activities (writing, discussing, observing and presenting)
- Greater emphasis is placed on students’ exploration of their attitudes and values (sharing idea and commenting)

**Research Findings and Discussions**

**Results from Documents Analysis and Classroom Observation**

Results of data analysis in lesson plans of four PSTs found that they taught by using active learning criteria in their teaching science as showed in the Table 2.
Table 2

*Results from lesson plans*

<table>
<thead>
<tr>
<th>Characteristics of active learning</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PST-A</td>
<td>PST-B</td>
</tr>
<tr>
<td>Interaction and collaboration</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Doing by themselves</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Analysis thinking or creating thinking</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Writing, discussing, observing, presenting</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sharing idea and commenting</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Note:* Group A; good performance before, Group B; not good performance before

There were two groups of them, one was a group of good performance (Group A) and another one was not good performance (Group B).

Results from classroom observation of each PSTs in three times found that they created active learning in their teaching science as following;

**Results of Classroom Observation of Pre-service Science Teachers (PST-A)**

She taught three topics including; fossils, dinosaurs in Thailand and extinction of living thing.

**Science teaching and students learning in the fossils topic.** PST-A given students observe the image of fossils and do classification kind of fossils. She encouraged students to brainstorm in classification type of fossils. Then, she asked questions to discuss and comment about the fossils. For examples, “how students know the type of fossils?” She provided students to write the answer in exercise book and present their answer. This teaching made students interacted with PST-A and classmates. Students observed image and classified kind
of fossils by themselves which made them brainstormed and analyzed together in group. In addition, students discussed and commented together about the questions. Students wrote and answer the questions in exercise book by themselves and present to classmate.

Science teaching and students learning in the dinosaurs in Thailand topic. PST-A provided students to observe and analyze the dinosaurs’ shadow in order to classify type of dinosaurs. Then, teacher randomly selected students in each group to pick dinosaurs’ image and putted it in a shadow on a board and used questions to let students participate in discussion and commendation. For example, "what does dinosaur look like?". Then, teacher provided students to brainstorm for answer and write answer in exercise book. Students observed and analyzed dinosaurs’ shadow for classification type of dinosaur. They picked dinosaurs image and putted in shadow on the board. Students discussed and commented about type of dinosaurs. They wrote by themselves and presented.

Science teaching and students learning in the extinction of living thing topic. Teacher given students observed and analyzed about extinction of dinosaur by watching video. She used questions and asked students to discuss, comment and analysis about extinction, "what are the causes of extinction of organisms?". Then she encouraged students to think together in order to answer and write their answer in exercise book by themselves. Students brainstormed and collaborated in order to answer the questions. Moreover, students could write the answer by themselves in exercise book about what they were thinking.

Results of Classroom Observation of Pre-service Science Teachers PST-B

The PST-B taught two topics including; the factors of photosynthesis (light and chlorophyll) and the qualitative of water.

Science teaching and students learning in the factors of photosynthesis (light and chlorophyll) topic. PST-B used questions and asked students to answer with classmate. She encouraged students to discuss and comment about the question, "why chlorophyll is needed
for plant in photosynthesis?”. In addition, she given students in each group to do experiment by themselves and students had to record and write the results of experiment. After finish experiment she provided students to present to other groups for discussing together.

**Science teaching and students learning in the factors of the qualitative of water topic.** PST-B asked questions to students answer; “how is feature the colure of water?”. Then, she provided students to do experiment by observing the color of water in each bottle and smelling of water. Teacher told students record experimental results while they did experiment and summarized in the end of experiment and recorded in their exercises book. In addition, teacher given all students present experiment their results to classmate. Students recorded experimental result and summarized what they have learned.

**Results of Classroom Observation of PST-C**

She taught three topics including; function of leaves (dehydration), factors necessary for plant growth (nutrient) and factors necessary for plant growth (light).

**Science teaching and students learning in the function of leaves (dehydration) topic.** PST-C given students look stomata by using microscope. Then, she provided students to design experiment and present experimental designed. Teacher encouraged students to discuss and comment in question, ”how do we know leaves are dehydrated?”, and provided students to write and answer questions in their exercises book. They observed and draw dehydration of plant by themselves. They brainstormed and designed experiment together in group.

**Science teaching and students learning in the factors necessary for plant growth (nutrient) topic.** PST-C provided students to design experiment and present what they designed. She let students do experiment and observe plants that got nutrient and do not got nutrient. She provided students to discuss and comment, “what happen if we bring nutrients for plants? and “why do you think that”. Teacher provided the students to write and answer
questions in exercises book. The students had observed, analyzed and brainstormed about the factors necessary for plant growth. Furthermore, the students discussed and commented in answers the questions.

Science teaching and students learning in factors necessary for plant growth (light) topic. PST-C asked students that, “why light is significant for plant?”, then she asked students to work in group to brainstorm and design experiment. Teacher given students present experimental design and asked students that, “how is the plant that gets light?”. Teacher and students had discussions together, then teacher provided the students to write the answer in exercises book. Students brainstormed to design experiment together in within group. Students interacted with teacher and classmate by brainstorming and analyzing data to find the necessary factors for plant growth.

Results of Classroom Observation of PST-D

She taught two topics including; surrounding substance and electricity.

Science teaching and students learning in the surrounding substance topic. PST-D used questions and asked students to discuss and analyze, "why the balloon does not crack over the fire?". In addition, teacher provided students to do experiment by themselves in group. She given students to observe and record results of heat transfer. In the end of study teacher given students present and asked students to comment their friend answers. In addition teacher guided students to think more, for examples “how do you utilize the convection heat in your life?. This teaching encouraged students interacted with teacher and classmates by doing experiment. They did experiments by themselves and collaborated in doing experiment in within groups. While they did experiment, they brainstormed to find the result, observed and recorded the result in experiment. After finish to do experiment they presented to classmate.
Science teaching and students learning in the electricity topic. PST-D encouraged students to use simulation in study circuit and given students observe the electrical circuit that their friend demonstrated in front of class. Then, students written and did exercises in the book. Teacher used questions and asked student to discuss, analyze and comment, “why the resistance in serial and parallel circuits are different?”. Then, teacher provided students to presents about electrical circuit to classmate. Students could be use simulation, other students observed and recorded the results from the simulation. In addition, the question of teacher provided the students to discuss, analyze and comment together by working in group.

Results from documents analysis and classroom observation, it showed that all of four PSTs created active learning in science teaching for their students including: 1) interacting, 2) collaborating, 3) doing activity by themselves, 4) observing, 5) higher or der thinking such as analysis, 6) discussing, 7) writing, 8) presenting. 9) brainstorming and 10) commenting.

Results from Interview

To confirm the results from the documents analysis and classroom observation, the interview was used. Four pre-service teachers and supervisor teachers were interview as showed in Table 3 and table 4.

Table 3

Result from interviews of four PSTs

<table>
<thead>
<tr>
<th>PSTs</th>
<th>Data of interviews</th>
<th>Grouping words</th>
</tr>
</thead>
<tbody>
<tr>
<td>PST-A</td>
<td>“I managed the class and used the <strong>questions</strong>, which my questions were <strong>discussed</strong> with my friends and supervisor teacher. “I improved activities and questions for students learning by <strong>observing</strong> my friend teaching and I was <strong>reflected</strong> by supervisor teacher after I finish teaching”.</td>
<td>- Questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discussion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Observation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Reflection</td>
</tr>
<tr>
<td>PST-B</td>
<td>“I used <strong>questions</strong> and asked students to answers together and give students do experiments by</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discussion</td>
</tr>
</tbody>
</table>
themselves in groups. The questions that used in teaching, I discussed with my supervisor teacher. I improve my teaching by observing my friend teaching and I was reflected by my supervisor teacher”

PST-C - “I asked students to answer the questions in groups and demonstrated experiment with students to do experiment together. The questions that I used in teaching were discussed with supervisor teacher and my friend. In addition, I observed my friend teaching and I was reflected by supervisor teacher after teaching”.

PST-D - “I give students do experiments and used questions to students answer together. My questions were discussed with my friend and my supervisor teacher. Sometimes I observed my friends teaching about what they used the questions to teach students. In addition, I was reflected after teaching by supervisor teacher and when I study in forth year ago in micro-teaching. This made me improve in my teaching”

Table 4

<table>
<thead>
<tr>
<th>Supervisor teachers</th>
<th>Data of interviews</th>
<th>Grouping words</th>
</tr>
</thead>
</table>
| Supervisor teachers of PST-A | “I introduced the questions in lesson plan for PST-A. She asked and talked about the questions all time with me. I reflected every time after PST-A teaching such as kind of questions, technique to use and ask the questions in activities. I saw PST-A discussed lesson plans with her friends, and during her friends teach PST-A went to observe her friends teaching”. | - Questions  
- Discussion  
- Observation  
- Reflection |
Supervisor teachers of PST-B

“I guided PST-B in creating questions in lesson plan and teaching activities. PST-B told with me and discussed questions and activities before her teaching. I advised and reflected in teaching after she teaching. I saw she adjusted the questioning in activity after she was reflected. In addition, PST-B observed her friend teach in classroom for adapt to her own class”

Supervisor teachers of PST-C

“I guided PST-C about the questions to use in teaching. PST-C improved the questions in lesson plans than before. PST-C adjusted her questions and activities after she got reflection from me. I saw PST-C discussed with her friends all time in doing lesson plans and observed other friends teaching”

Supervisor teachers of PST-D

“PST-D discussed with me about creating activities and questions. I reflected after PST-D teaching, which made she adjusted activity and questions suitable the context of students in class. In addition, PST-D observed the teaching and learning of teachers and her friends teach in class. Then she adapted activity and questions for own teaching”

In the Table 3 and 4 showed that, there were four words consisting of: Questions, Discussion, Observation and Reflection for supporting pre-service science teachers to create active learning activity. The data from the interview relevant with the data from documents analysis and classroom observation and these factors corresponding with the previous researchers that; teachers have to use questions in teaching and create questions on different levels for students learning in order to students participate in class (Moustafa & Zvi-Assaraf, 2013; Bonwell & Eison, 1991; Vickery, 2014, p. 20). Developing questions teachers need to discuss for explanation and resonation in the content. There is extended ideas essential in the development of thinking skills (Michaek, 2006). In addition, good teachers are active
observations in students’ learning. Teachers need to see students working in small group and listen to student comments during small group to determine how students are applying science concepts. Furthermore, teachers can define and confront in their teaching and learning science by reflecting (Abell & Bryan, 1997), which reflection involve monitoring what happens in the process of teaching and learning (Vickery, 2014, p. 20).

**Conclusion**

The results from the documents analysis, classroom observation and interview showed that four pre-service science could be develop themselves to create active learning professionally in teaching science by using four factors as following:

- Observation of teaching and learning: observe their friends’ class
- Question of teaching and learning: practice in constructing the questions to ask students interactively
- Discussion of teaching and learning: create lesson plan with discussion group
- Reflection of teaching and learning: receive the feedback after their teaching

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Nature of Science in Students’ Conceptions of Scientists: A Pilot Study of an “Act a Scientist -Test”

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Abstract

Testing students’ of conceptions of science can facilitate their understanding of the nature of science (NOS) and inform their career choices. While drawing-based tests exist, alternative tests are required to measure students’ more complete images of science. This pilot study introduces a novel act-like-a-scientist test (ALAST) to capture conceptions about actions associated with science. The pilot was conducted on 28 bachelor-level science students who wrote down scientist actions and mimicked them for peers who identified the actions. The lists of different scientist actions were analyzed using deductive content analysis. Mimicking the actions of scientists was found to represent a broad image of NOS, including epistemic-cognitive, social-institutional and emotional domains of sciences. Moreover, ALAST opens up the possibility for multi-faceted representations, supported communication and deconstruction of stereotypes. Some of the challenges to ALAST include the over-emphasis of science as action, the difficulty of mimicking abstract ideas, and distinguishing individual conceptions. While ALAST was considered successful in this study, more research is needed to develop and validify the test.

Keywords: Nature of science, science conceptions, drama, assessment
Nature of Science in Students’ Conceptions of Scientists: A pilot study of an “Act a Scientist - Test”

Developing more authentic conceptions of scientists’ work has the potential to promote students’ understanding of the nature of science (NOS) and assist them in career choices. Research indicates that students across all age groups possess unrealistic and gendered conceptions of scientists. While such conceptions are formed implicitly, i.e. through media (Losh, Wilke, & Pop, 2008) and science teachers, they can be explicitly addressed with the assistance with tests and reflection such as Draw-a-Scientist Test (DAST) (Finson, Beaver, & Cramond, 1995). However, DAST is criticized for not providing the space to reflect the complete array of students’ conceptions (Reinisch, Krell, Hergert, Gogolin, & Krüger, 2017). To provide new, complementary tests to explore inherent conceptions, approaches have been drawn from art (Turkka, Haatainen, & Aksela, 2017). In this study, we piloted an Act-like-a-Scientist Test (ALAST), in which bachelor-level chemistry students express their conceptions by acting like a scientist. This study is part of a design-based research (Edelson, 2002), which aims to develop assessment for the teaching of nature of science (NOS) through drama in science education.

Theoretical Background

Science education aims to promote scientific literacy of students so that they can live with a better understanding of the natural world in the future (DeBoer, 2000). Becoming scientifically literate is based in the understanding of nature of science (NOS) (Dagher & Erduran, 2016). While no consensus of an exact definition of NOS exists, it can be generally characterized by questions such as what science is, how it works, how scientist operates and how science and society interact (McComas, Clough, & Almazroa, 1998). These questions embed a certain image of a scientist, which can be explored to promote students’
understanding of NOS. To understand how students’ conceptions about a scientist relate to the nature of science, we chose a reconceptualized framework of NOS by Dagher and Erduran (2016) because it provides a holistic representation of the range of work involved in being a scientist and includes specific categories, such as “scientific practices” and “professional activities,” that capture the conception of a science as defined by the actions of a scientist.

Moreover, the theoretical focus of the reconceptualized model of NOS on “science as enterprise” allows the beliefs and values related to science as a career to be better understood. These beliefs and values related to science as a career together with students’ beliefs about themselves and their abilities have been argued to influence students career choices (Dick & Rallis, 1991). In other words, students might be more likely to choose a career if they can identify with those within that profession.

Identifying with a scientist can be a challenge for many students. The prevalent conception of a scientist as a middle-aged male, working alone has been documented since the 1950s across age-levels and cultures (Chambers, 1983; Finson, 2002; McCarthy, 2015; Reinisch et al., 2017). This conception stems from diverse sources including media (Losh et al., 2008; Pansegrau, 2008), cultural stereotypes and various social influences such as parents, friends and science teachers (Dick & Rallis, 1991) that emphasize science as academic, strongly intellectual, abstract and decontextualized (Christidou, 2011). So far, these stereotypical conceptions of scientist have been measured with instruments such as Draw-a-Scientist Test.

**Draw a Scientist – Test**

Chambers' (1983) Draw-a-Scientist Test asks participants to draw their image of a scientist on a sheet of paper. The advantage of DAST is that it is not affected by students’ writing skills and can be completed quickly (Finson et al., 1995). These drawings have been
analyzed to reveal stereotypical images of a scientist, enumerated in a checklist by Finson et al. (1995) such as a lab coat, eyeglasses, facial hair, symbols of research, symbols of knowledge, technology and scientist captions, male gender, Caucasian, indications of danger, presence of light bulbs, mythic stereotypes, indications of secrecy, indoor setting and middle-aged/elderly. The stereotype varies between groups. ‘Facial hair, mythic stereotypes, secrecy, elderly images and danger’ were not found in the pre-service teachers’ drawings (McCarthy, 2015). Similarly, Reinisch et al. (2017) report that pre-service teachers do not care about appearance of the scientist and recommend dropping ethnicity and adding a neutral gender to DAST questionnaires.

DAST has received criticism. For example, the interpretations of drawings might depend on the relative drawing skills of students (Losh et al., 2008). Reinisch et al. (2017) recognize the difficulties in interpreting the symbols in the drawings and suggest that other sources of data, such as questionnaires and interviews, should be used to verify meanings. Moreover, they suggest that results should be evaluated in the light of the prompt. For example, the prompt “Draw a scientist” implies that students should draw just one scientist, while students may possess several definitions for the word scientist (Finson et al., 1995), or they might be encouraged to draw stereotypes instead of their own conceptions, for the sake of making their drawings more recognizable to their peers (Reinisch et al., 2017). In addition, the simple prompt might encourage students to focus on the appearance of a scientist, making it difficult to capture the nature of science aspects embedded in the actions of a scientist.

Farland-Smith, Finson, Boone and Yale (2014) modified the prompt to emphasize the appearance, location and activities of a scientist, therefore enabling a broader representation of science.

Recognizing the criticism of DAST we sought complementary assessment of students’ conception of a scientist. We drew from art integration pedagogic methods (Turkka et al., 2017) and developed a pilot test based on drama to explore scientist actions.
Expressing Internal Conceptions with Drama

Drama strategies have been suggested as a teaching method to learn about science concepts, the nature of science and interaction of science and society (Ødegaard, 2003). Dorion (2009) reports that drama enables participants to communicate abstract meanings multimodally, using non-verbal means such as gestures, space, movement and body language. Students’ gestures have been suggested to help the teacher to recognize pre-articulate ideas, distinguish in-between explanations and descriptions, display a novelty of ideas and facilitate idea construction (Scherr, 2008). Drama strategies such as improvisation and mimicking provide opportunities for students to improvise movements and gestures to reveal conceptions and reconstruct these conceptions. Moreover, drama strategies can encourage students to “act like a scientist” to momentarily adopt not only the thoughts but also the emotions of a scientist (Turkka & Aksela, in review), facilitating empathy towards scientists and through that a rich and personal way of understanding science (Duveen & Solomon, 1994). While science is often considered devoid of emotion, understanding of emotions in science can contribute to the understanding of the nature of science. Emotions, for example, are irreducible part of personal motivation for science and social fabrication of science (Barbalet, 2002). Finally, in comparison to drawing how a scientist looks from a distance, improvising a scientist’s actions could provide more immediate and emotional expression through an inside-out perspective, therefore revealing more implicit thoughts and assumptions and students’ authentic conceptions of a scientist.

Methodology

The goal of this study is to provide a proof of concept for the Act-like-a-Scientist Test (ALAST). This pilot study is part of a larger research program aiming to develop formative assessment of teaching about nature of science with drama in science education. The questions that guided this research were:
• What aspects of nature of science can be expressed by mimicking actions of scientist?

• What are the advantages and disadvantages of ALAST?

In ALAST, students are prompted to “imagine what a scientist does” and individually write down as many relevant actions as possible. Then a game is introduced to the students, whereby the students mime the actions on their list to a group of peers, who to try to recognize them. When a peer recognizes what action is being acted out, s/he shouts it out and the student who is acting can move to the next word on his/her list if their action has been correctly identified. The students take turns acting out their list of actions. The student who acts out the most words on his/her list in two minutes time will win the game. ALAST is introduced as a game to make the test more engaging and to reduce time to think in order to capture more immediate ideas about science. Afterwards, a moderator of the game can guide reflection about which types of NOS-conceptions appeared in the game.

A pilot of ALAST, as described above, was conducted with 28 bachelor-level chemistry students organized into test groups of seven people. One of the groups were studying to become science teachers. The students at this level have not had any education about NOS in the university and were not introduced to the NOS-framework before the test but were briefed on it afterwards during the reflection. The material gathered for this study consists of the individual word lists of the students. The words in these lists were marked if they were successfully recognized by peers. The original lists were in Finnish and were translated to English.

The material was analyzed with deductive content analysis (Mayring, 2014). The category system (Table 1) is modified from a reconceptualized model of NOS (Dagher & Erduran, 2016), which distinguishes between epistemic-cognitive and social-institutional dimensions of nature of science.

We introduce an additional emotional domain to the framework, following suggestions from a history of science framework that suggest that teaching empathy can be
critical to helping students connect with and deconstruct the culture of science (Güney & Seker, 2012). While the existing framework was well-suited to capture conceptions of the exterior worlds of a scientist, the emotional dimension is introduced to capture more humanistic conceptions students have about what it is like to be a scientist.

Table 1

Main categories

<table>
<thead>
<tr>
<th>Cognitive-epistemic</th>
<th>Social-Institutional</th>
<th>Emotional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific practices [NOS1]</td>
<td>Professional activities</td>
<td>Emotional experiences</td>
</tr>
<tr>
<td>Aims and Values [NOS2]</td>
<td>[NOS5]</td>
<td>[EMO]</td>
</tr>
<tr>
<td>Methods and methodologies</td>
<td>Scientific ethos [NOS6]</td>
<td></td>
</tr>
<tr>
<td>[NOS3]</td>
<td>Social certification [NOS]</td>
<td></td>
</tr>
<tr>
<td>Scientific knowledge [NOS4]</td>
<td>Social values [NOS8]</td>
<td></td>
</tr>
</tbody>
</table>

The reconceptualized model of NOS introduces scientific practices and professional activities as ways to understand science as action. For the purposes of this study six other categories were modified into form of action. The coding of the “scientist actions” to all of these categories together are presented below in Table 2 together with anchoring examples found in the sample.

Table 2

Coding scheme

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition of category (modified from Dagher &amp; Erduran (2016)).</th>
<th>Anchor examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOS1</td>
<td>Actions related to scientific practices such as observing, asking questions, gathering and documents, compares, boils</td>
<td></td>
</tr>
</tbody>
</table>
classification of data, designing an experiment, 
creating models and theories, creating hypothesis

<table>
<thead>
<tr>
<th>NOS2</th>
<th>Actions that directly refer to aims and values of science such as consistency, objectivity, simplicity and novelty. Examples would be ensuring objectivity, inter-coding, calculating reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ensembles big pictures, reforms, rejects</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOS3</th>
<th>Actions that refer to methods and methodological choices linking values and practices such as choosing appropriate methodologies to ensure validity and reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Revises, repeats, verifies, pilots</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOS4</th>
<th>Actions related to using the entities of scientific knowledge such as modelling and theorizing (in comparison to scientific practices that create this knowledge)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOS5</th>
<th>Professional activities such as attending a meeting, applying for funding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Attends meetings, sits</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOS6</th>
<th>Scientific ethos in scientist actions such as criticizing and respecting the nature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calls into question, criticizes, toadies, plots,</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOS7</th>
<th>Actions that relate to Social certification and dissemination of scientific knowledge such as peer-reviewing and publishing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Publishes knowledge, networks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOS8</th>
<th>Actions that relate to social values of scientist actions such as creating solutions for problems or innovations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Innovates, benefits, produces value</td>
</tr>
</tbody>
</table>
EMO  Actions that describe emotions or affections related to science or emotions of a scientist  Gets confused, gets frustrated, is surprised, fails, succeeds, hesitates, fusses, plays

---

**Results**

In the study, 194 scientist actions were coded as representing one of the emotional-cognitive, social-institutional and emotional categories. A total number of 89 of the 194 were coded as distinct actions after considering crossovers in each individual list. The category frequencies are represented in Table 3.

**Table 3**

*The frequency of scientist actions representing the different areas of NOS*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Different actions</th>
<th>Recognized by peers</th>
<th>Unrecognized by peers</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epistemic-cognitive</td>
<td>NOS1 23</td>
<td>70</td>
<td>22</td>
<td>92</td>
</tr>
<tr>
<td>NOS2 6</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>NOS3 4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>NOS4 0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>TOTAL 33</td>
<td>73</td>
<td>30</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>Social-institutional</td>
<td>NOS5 30</td>
<td>40</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>NOS6 6</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>NOS7 3</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>NOS8 4</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>TOTAL 43</td>
<td>47</td>
<td>28</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Emotional</td>
<td>EMO 13</td>
<td>6</td>
<td>10</td>
<td>16</td>
</tr>
</tbody>
</table>
Epistemic-cognitive actions were the most frequently observed (N=103). These included 33 different scientist actions that students generated. The three most frequently actions were researching, thinking and experimenting all of which represented Scientific Practices (NOS1). The actions related to the sub-categories of Aims and Values (NOS2) and Methods and Methodologies (NOS3), such as reforming or revising, were rare. No actions related to Scientific Knowledge (NOS4) were found in the sample.

While social-institutional actions were less frequently written in students’ papers (N=75), these consisted of a wider variety of different actions (N=43) than epistemic-cognitive actions (N=33). The most frequent epistemic-cognitive category was professional activities, e.g. writing and discussing (NOS5). The less frequent social-institutional sub-categories were Ethos of Science (NOS6), Social Certification and Dissemination (NOS7) and Social Values (NOS8). Within these, all of the NOS7 actions were successfully recognized by peers.

Emotional actions were less frequent (N=16) than the other main categories. The actions within this category were more often unrecognized by the participants than in the other categories. The actions that occurred more than once within this category were “wondering,” succeeding and getting interested.

The Possibilities and Challenges

Table 3 illustrates some of the possibilities of ALAST. First, a total number of 89 different actions indicates that ALAST can provide a broad representation of scientist actions and not just one-sided conception of a scientist. Second, the majority of the written actions were also recognized, indicating that students can communicate actions to their peers through mimicking. Third, the imbalance in recognizing epistemic-cognitive vs. social-institutional
scientist actions indicates that a certain stereotype exists in the group, which allows students to reflect on that stereotype.

Similarly, Table 3 illustrates some of the challenges related to ALAST. First, the categories that were not based on actions were less represented, indicating that the prompt needs to be developed further to enable more detailed reflection. Second, there were categories which were rarely communicated to others, indicating that there might be certain type of abstract actions which are challenging to communicate through mimicking. Third, Table 3 represents only groups shared conceptions. From the current design of ALAST, it is meaningless to quantitatively assess individuals conceptions of science from the number of successfully communicated scientist actions, because this amount is likely to depend on mimicking abilities as well as students’ abilities to read each others’ body language.

Conclusions and Discussion

The NOS Scope of ALAST

The occurrence of both epistemic-cognitive and social-institutional actions indicates that the ALAST has the potential to capture different aspects of NOS through scientist actions. Within our sample, the more frequent scientist actions were epistemic or cognitive, such as experimenting or thinking. The epistemic actions align with the findings of Reinisch et al. (2017) who report that activities that students draw in modified DAST are significantly related to inquiry. The ALAST has the potential to complement this by exploring cognitive actions, which have been only symbolically represented in drawing (e.g. light bulbs above scientist heads). Mimicking enables dynamic representation of what is happening beyond one static frame, as the case with drawings. Moreover, emotional expressions have not been focused on with DAST, but appeared without specifically being prompted for in ALAST. The possibility to express emotions contributes to the ability to test conceptions of a scientist more broadly. Being able reflect on scientist emotions after the test opens up further
possibilities to promote understanding of the science as a human endeavour (Dagher & Erduran, 2016). While Dagher and Erduran (2016) do not specifically emphasize the emotions in the scientific process, they are irreducible parts of both scientific motivation and the social fabrication of science and can broaden the understanding of science (Barbalet, 2002). Finally, the sub-categories that were not directly “action-based” were rare, such as scientific knowledge, which was not found in the sample. In principle, scientist actions, such as theorizing or modelling could have covered scientific knowledge area of NOS. More research is needed to see if this type of actions can be captured with ALAST.

The Possibilities of the ALAST

The results reveal the possibilities of ALAST. First, the 89 different actions written in the list of actions indicate that ALAST can provide a multifaceted image of scientist. Second, the high ratio of successfully identified scientist actions point toward supported communication through mimicking. Even rather abstract cognitive actions such as analyzing were recognized by peers. This aligns with Dorion's (2009) conclusions that nonverbal gestures and movement support the communication of abstract ideas in science. The successes of communication through mimicking could be explained in part by early acquisition of the motor-sensory skill required for ALAST, which is based on imitation, a cognitive exercise practiced by newborns (Meltzoff & Moore, 1983). However, the “easiness” of communication with ALAST cannot be taken for granted in every case, because acting in front of one’s peers can be emotionally challenging for some of the students (Turkka & Aksela, in review).

A third possibility has to do with deconstruction of a science stereotypes. In this study the students emphasized science as epistemic-cognitive actions, which aligns with the stereotype of a science as academic, and strongly intellectual practice (Christidou, 2011). This enabled an instant in-group reflection on this image and offered possibilities to discuss
alternative images of science. A future possibility is to mimic alternative images of a scientist after this type of reflection in order to facilitate the construction of new ideas (Scherr, 2008).

The Challenges of the ALAST

The results indicate challenges to employing ALAST. The lack of representation of sub-categories not originally based on action indicate an imbalanced emphasis on science as action. The analytical framework needs to be developed further to understand how these actions relate to other aspects of NOS. The imbalance arises from the difficulty to infer the meaning of an action without a broader context. A similar problem is recognized in DAST: it is difficult to analyze polysemous meanings and additional clarifications are always needed (Reinisch et al., 2017). One future possibility to develop ALAST would be to experiment with mimicking specific situations or contexts based on the NOS categories. Another modification would be to mimic in pairs, or in a group, to encourage acting out science as social interaction.

Second, some of the abstract actions such as reforming or revising were not identified by peers, which indicates a challenge in representing certain abstract NOS ideas. More complex actions require more mimicking of a context, which might require more time to think. Mimicking challenging words could be beneficial because it would require students to think what is at the core of these actions in order to communicate them for their peers.

Third, the acting is done within and for the group, and it is meaningless to quantitatively assess individuals level of NOS-understanding from the results. The number of successfully identified actions are very likely to tell more about individuals’ ability to act and read body language, rather than the individuals’ informed views of science. Doing well in the mimicking encourages students to specifically express stereotypes of a scientist, instead of one’s own conceptions. Finally, students who mimicked the actions on their list later in the game had the opportunity to see how their peers mimicked particular actions, making it easier
to act out those concepts by relying on the same actions employed by their peers if those actions were also on their lists. That would also affect the amount of time it takes them to successfully act out an action if they save the time of thinking about how to act a given action out, and their partners save the time of having to uniquely identify that action.

**Implications**

ALAST is an novel way to measure students conceptions of a scientist. ALAST was found to illustrate scientist emotions, which creates prospective ground for the development of empathy and, through that, a more personal understanding of science (Duveen & Solomon, 1994) (Duveen & Solomon, 1994). Moreover, engaging students with ALAST enables a teacher or the researcher to ask a range of fundamental questions that help students to reflect their own NOS conceptions. This makes ALAST a valuable test for teacher education courses dealing with NOS. Some exemplary questions would be: which words were difficult to mimic and why; do the mimicked scientist actions represent your own ideas about science; what aspects of science are missing?

While the pilot of ALAST was successful, more research is needed to validate and develop the test. For example, video recordings are needed to analyze the mimicked actions in detail to analyze if the gestures illustrate more hidden aspects of the participants inherent conceptions of the nature of science, than mere written scientist actions (see i.e. Scherr, (2008). Finally, we recommend science teacher educators and researchers introduce ALAST as an alternative and engaging version of a test of students’ conception of a scientist.
References


Generating Scientific Explanation: The Effects of Generate an Argument Instructional Model on Newton’s Laws of Motion Classroom

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Abstract

In studying a science subject in classroom, to generate scientific explanations by means of using scientific claim, evidence, and reasoning is deemed as an important and necessary skill for students to demonstrate their own understandings of certain situations. To apply the Generate an Argument Instructional Model or GAI Model with teaching a science subject in classes is accordingly an approach to enhance students’ scientific explanations since this GAI Model was specifically designed to open up an opportunity for each group of students to develop possible claims which eventually lead to reasonable answers of certain questions based on available data set. In a part of the GAI Model’s process, all groups of students were required to create tentative arguments for providing claims and evidence. These contents were then identified in their communication media and reviewed later by their classmates. In this regard, each group had a chance to share their own opinions during such argumentation session. When bringing them to the end of the session, each group could eventually improve and revise its initial arguments and make them much better. It can be said that, with all stages of the GAI Model, students could learn how to argue about evidence; how to evaluate fact; and how to communicate information with the others on the grounds of scientific theories effectively.

This research study aims to investigate the effects of using the GAI Model on the ability in generating the scientific explanations which is deemed as a significant factor in learning a science subject for secondary level education. With respect to the investigation, an examination was also required to assess and record science explanation skill level of each student. The scientific explanation performance test with reliability at .86 was then applied to 42 ninth-grade students who were studying in a science class at a demonstration school in Thailand. In this scientific explanation performance test, it consisted of six main questions which each of those correlated to Newton's Law of Motion. The students were then asked to give the scientific explanations with three key components, viz. scientific claim, evidence,
and reasoning. Upon this basis, the Researchers did create criteria for assessing and leveling the scientific explanation scores for each student and determine the quality of the evaluation criteria by using inter-rater reliability.

The data collection of the scientific explanations was divided into three steps. Firstly, for preparing the students’ readiness, a teacher educated the students in order to make them thoroughly understand a method of developing scientific arguments and a role of the students towards teaching after quizzing them with the pretest. Secondly, the GAI Model was applied to teach the students in the classroom and test them repeatedly with the same questions after that. Shortly afterwards, the data was analyzed by using mean scores and standard deviation while the mean was compared by using paired sample t-test. The findings revealed that the students were capable to significantly improve their abilities to describe all key components of scientific explanation (p< 0.05). Finally, the students were questioned by using a semi-structured interview. Most students had the same answers that the GAI Model could help them refine their explanations, explain the scientific phenomenon, and develop their communication and presentation skills effectively. Therefore, it can be concluded that applying the GAI Model in the classroom could undoubtedly enhance the students’ abilities in generating their scientific explanations for learning the scientific conceptualization. As strongly believing that this GAI Model can be used to improve other students’ skills, in the next section of this research study, we will elucidate the GAI Model and discuss whether or not it actually has effects on the Newton’s Laws of Motion Classroom.

*Keywords:* Scientific Explanation, Generate an Argumentation Instructional Model, GAI Model, Newton’s Laws of Motion Classroom
Generating Scientific Explanation: The Effects of Generate an Argument Instructional Model on Newton’s Laws of Motion Classroom

The Programme for International Student Assessment (PISA), organized under the Organization for Economic Co-operation and Development (OECD), is an international assessment of students’ science literacy in which several countries have participated, such as Thailand. Thailand has attended this Programme since 2000 for a purpose of evaluating the science literacy of Thai students. Unfortunately, the result revealed that the scientific assessment of Thai students was indeed below the OECD average scores; furthermore, the scores continuously decreased in following years. In the PISA Scientific Literacy Assessment in 2015, Thai students were assessed again and challenged to provide correct answers with three competencies required, viz. (1) to explain phenomena scientifically; (2) to evaluate and design scientific enquiries; and (3) to interpret data and evidence scientifically (OECD, 2015: 19). Thailand still got the scientific average scores of 421 while the OECD average was 493 (IPST, 2013). This assessment could reflect the fact that Thailand’s education system had not been developed enough. It is more likely to say that Thai students may be in the future faced with tough competitions since their competitiveness cannot be developed as much as it should be.

To resolve the aforementioned problems and make real progress in Thai students’ science literacy, Researchers have an opinion that constructing clear and rational explanations can help students achieve accurate and better understandings about the nature of scientific knowledge in terms of its connection to evidence, its uncertainty, and its subjectivity to change (Ruiz-Primo et al., 2008). Written explanation was also recommended on this matter since it has been argued that if students provided their scientific explanations in writing, this could reflect what they have learned and understood clearly in a way that differently from oral discussions in classrooms (Tishman & Perkins, 1997). Thus, to generate a scientific
explanation was an important ability to promote for students practice a thinking skill with learning how do the scientists discover scientific knowledge, and learn about scientific process with linking three component, viz. scientific claim, evidence, and reasoning from do activities (McNeill & Krajcik, 2008).

According to the study of many concepts and researches, an argumentation is one of many processes used for constructing explanations. It has been studied that a goal of developing the science literacy and reasoning is the argumentation because it is unquestioningly accepted worldwide as the main process to build knowledge as well as make people think and act like scientists. Moreover, the argumentation is consistent with the principle of scientific knowledge which is a scientific inquiry – a method of creating knowledge or explanations developed by providing meaning, information, and presenting explanations that is made to society in order to be refined (Sampson & Clark, 2009: 448). The construction of written scientific explanations should be considered at the heart of the scientific inquiry and should be emphasized in every science class in which scientific inquiry teaching takes place (Ruiz-Primo et al., 2008).

The argumentation can bring students a great deal of advantages (Dawson & Venville, 2010). Firstly, argumentation is one process of developing and validating scientific knowledge. In many steps of the scientific argumentation, students have opportunities to debate and share their own understandings of scientific concepts with the others. Secondly, it enhances the ability in learning science because speaking or writing with arguments can describe scientific concepts effectively. Thirdly, after having a clear understanding of such scientific concepts by virtue of the argumentation, it shall lead students to decision-makings easily. Furthermore, encouraging students to make the scientific arguments can provide them an opening to create definitions at both of the individual and social levels. It also provides good strategies for assessing and criticizing specific scientific evidence. Last but not least, the argumentation can help develop the understanding of the science subjects; motivate students
to behave in the same way as scientific society; as well as create knowledge by using evidence and reasoning. There are great deals of benefits that students will obtain from the argumentation.

Therefore, the objective of this research study is to examine the effects of the Generate an Argument Instructional Model or GAI Model on students’ capacities to generate the scientific explanations. Specifically, the Researchers hereby raise a question whether the GAI Model can increase the levels of ability to generate the scientific explanations and understandings on the Newton’s Laws of Motion or not.

The Generate an Argument Instructional Model

The Generate an Argument Instructional Model developed by the educators Victor Sampson and Jonathan Grooms in 2010 was created to develop in-depth understanding of the scientific explanations and to sharpen reasoning, critical thinking, and communication skills. Sampson and Grooms suggested that the Generate an Argument Instructional Model was designed to provide small groups of the students the opportunities to develop their claims for answering questions according to problems based on the data available. As part of this process, all groups were required to generate tentative arguments providing claim and evidence. These contents were then identified in their communication media and reviewed later by classmates. In this regard, each group had an opportunity to debate and shares its own ideas during the session argument. As aforementioned, it proved that the GAI Model could provide many useful benefits for teachers because it could be subsequently applied as a template or guideline to design science learning by aiming at describing the contents of existing curriculums. The next section is to describe five stages of Generate an Argument Instructional Model which are problem and task; generation of tentative argument; the argumentation session; reflective discussion; and final written argument.
Method

Research Context and Participants

The mixed method research was used to investigate the level of scientific explanation through the GAI Model procedures which were applied to the Newton’s Laws of Motion classroom. 42 ninth-grade students enrolling in a science course during the second semester of the 2017 academic year at the Demonstration School of Ramkhamhaeng University participated in this investigation process. Levels of scientific explanation performance were evaluated and collected data from these students more than four weeks which was to be a quality data. Meanwhile, level of this ability was converted to a quantitative data and analyzed by comparing between pre- and post scores. After that, students were questioned by using a semi-structured interview. These process would be the key data to answer that could the GAI model encourage students generate scientific explanation, and how did.

Instruments

The instrument used to collect the data was the Scientific Explanation Performance Test (SEPT) which was a reliability at .86, comprising of six main questions which each of those was correlated to the Newton's Laws of Motion Concept. In all questions, the students were required to explain their answers with three components of the scientific explanation – scientific claim, evidence, and reasoning. The examination was given to these students twice, before giving method (pretest) and after giving method (posttest). After that, another instrument was the semi-structure interview applied to ensure that the GAI Model actually did encourage the students to develop generating and proving their scientific explanations.

Teaching Intervention

The Generate an Argument Instructional Model was applied as an intervention in the study. For the students’ readiness, a teacher educated the students and makes them thoroughly understand the following three issues, viz. (1) the nature of the scientific argument; (2) the
method of argumentation and peer review; and (3) the role of the student in the scientific argument. As shown in Figure 1, this GAI Model consisted of five steps (Sampson, V., and Schleigh, S., 2012). At first, the teacher aroused interest to the students and connected their prior knowledge with the phenomena to be studied. After that he defined and explained the activities that these students were required to do. The purpose of this stage was to capture the students’ attention and make them engage in the activities. Secondly, each group made a tentative argument consisting of claim, evidence (the data that has been analyzed and interpreted), and reasoning in its communication media as well as explained why the evidence they decided to use was deemed important. Thirdly, the students were given an opportunity to debate, share, evaluate, and revise their investigations with their classmates. Fourthly, some groups of the students were suggested to modify their tentative arguments or conduct an additional data analysis if needed. Lastly, each student was required to demonstrate knowledge that he or she had learned by producing a final argument in writing. At the end of session, the teacher and students made a discussion on the evidence and concluded this experiment with a core concept. Three GAI laboratory activities were also designed for and implemented by all participants. This research study was administered more than four weeks.
Data Collection

After the students completed the pretest, the GAI steps began with the Newton’s Laws Concept by using the SEPT. All of questions were used to requisite the students in order to make them explain how and why the phenomena of the concept happened by expressing three required components of the scientific explanation which are claim, evidence, and reasoning. Again, the SEPT was given to the students after an implementation of the GAI Model. The posttest’s result was then used to evaluate the improvement and development of the students’ scientific explanation performances. The students’ opinions gained from the semi-structured interview were also interpreted as a clarification of how to generate the scientific explanations through the GAI Model implementation.

Data Analysis

The students’ ideas including scientific claim, evidence, and, reasoning gathered from the SEPT were analyzed to determine three qualitative levels of the scientific explanation
performances as illustrated in Table 1. This scoring rubric was adapted from a rubric scheme of McNeill and Krajcik, 2008.

Table 1  

**Scoring Rubric of Scientific Explanation Performances**

<table>
<thead>
<tr>
<th>Levels</th>
<th>Components of Scientific Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(Scores)</strong></td>
<td><strong>Claim (C)</strong></td>
</tr>
<tr>
<td><strong>Level 0: L₀</strong></td>
<td>No claim or a claim is not consistent with a question (CL₀).</td>
</tr>
<tr>
<td><strong>(0 point)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Level 1: L₁</strong></td>
<td>A claim consists with a question but not clear (CL₁).</td>
</tr>
<tr>
<td><strong>(1 point)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Level 2: L₂</strong></td>
<td>A claim is correct and consistent with a question (CL₂).</td>
</tr>
<tr>
<td><strong>(2 points)</strong></td>
<td></td>
</tr>
</tbody>
</table>
The students' scientific explanation performance scores taken from the pretest and posttest were analyzed with a normality test to indicate the students’ prior knowledge on the Newton’s Laws Concept; furthermore, both tests were compared by using mean scores, standard deviation, and paired sample t-test so as to investigate whether or not the GAI could foster the students’ scientific explanation performances.

**Results and Discussion**

The pretest and posttest data were analyzed and classified into three levels – 0, 1, and 2 based on three components of the scientific explanation — claim (C), evidence (E), and reasoning (R) to illustrate how and why the phenomena of the concept happened; for example, a situation of the Newton’s 3rd Law as followed:

**Claim**

In the situation in Figure 2, the students were asked to give an explanation with the Newton’s 3rd Law Concept: “When the boy and elephant were pulling a rope tied with spring scales in opposite directions, what is size of the forces, F1 and F2?”

<table>
<thead>
<tr>
<th>Experiments</th>
<th>Size of Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boy (F1)</td>
</tr>
<tr>
<td>1</td>
<td>499</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
</tr>
<tr>
<td>3</td>
<td>501</td>
</tr>
<tr>
<td>Averages</td>
<td>500</td>
</tr>
</tbody>
</table>

*Figure 2. Situation of the Newton’s 3rd Law.*
According to the answers given in the pretest, a student claimed that “the boy and elephant was pulling the rope in opposite directions with equal size of the forces and this made the rope immovable”. This claim indicated that the student had a correct idea which was consistent with the question. Similarly in the posttest, the student argued that “the forces of the boy and elephant pulling the rope were equal in size too”. Both of such results clearly indicated that the student was able to claim with correct ideas and reached the level 2 of the scientific explanation performance (CL2) as shown in Figure 3.

The students are required to consider the schedule of the experiment’s result and answer the following questions:
5.1 How is the size of forces produced to the student and elephant’s spring scales when they are playing tug of war? “Same size of forces / The rope is still in the same position”.

Figure 3. Examples of the Student’ Claim about the Newton’s 3rd Law Situation between the Pretest and Posttest.

Evidence

According to the student’s aforementioned claims, he also had to provide evidence supporting his claim and present his idea about how he knew that both of the boy and elephant pulled the rope in opposite directions with equal size of the forces. In Figure 4, it showed that, in the pretest the evidence the student gave from his understanding was that “although the boy and elephant had different size and shape of bodies, they exerted the same size of forces in
average while pulling on the rope in opposite directions. This accordingly caused the rope to stay still". His data identified the evidence from the experiment but rather unclear to support his claim. Thus, it was classified in level 1 (EL1).

5.2 What information or evidence does the student have to support its answer in Question 5.1?

"From the schedule, the sizes of the boy and elephant’s forces are the same. As having the equal size in average, this makes the rope stay still and not movable".

"From the schedule, the 1st time is 500:499; the 2nd time is 499:498; and the 3rd time is 501:503. The average is 500:500. Therefore, the elephant and boy exert the rope with equal size of the forces".

Figure 4. Examples of the Student’s Evidence Identified to Support his Claim on the Newton’s 3rd Law Situation in the Pretest and Posttest.

The posttest in Figure 4 illustrated that the data provided by the student was more than previously identified in the pretest. This data based on the experiment in the situation was the interaction between the boy’s force (F2) and the elephant’s force (F1) acting on the spring scales connected to the rope. When data was analyzed by a used average, it could be said that the size of force of the boy was equivalent to that of elephant. Thus, the forcing of them was equal. This data was accordingly classified in level 2 (EL2) because the evidence was clear enough to support his claim in this situation.

Reasoning

Reasoning is a necessary component which explains the Newton’s Law Concepts by linking a claim with evidence in order to describe how the situation occurred. In Figure 5, the
student gave an explanation by using a force diagram to present the size and direction of the forces and describe how the F1 was equal to F2 when the boy and elephant was pulling the rope. The student had an idea that because the F1 was equal to the F2, there were a refutation which made the rope immovable. Although this reason was consistent with the situation and linked with their claims and evidence, but the student still had misunderstanding of the Newton’ 3rd Law of Motion Concept. Thus, the students’ performance was evaluated to level 1 (RL1).

5.3 Does the student have any scientific principle or theory to describe or give a reason for linking the answers provided in Question 5.1 and 5.2?

"As both forces are refuted each other, the rope stays still".

(Force Diagram)

5.3 Does the student have any scientific principle or theory to describe or give a reason for linking the answers provided in Question 5.1 and 5.2?

"According to the Newton’s 3rd Law of Motion Concept, an action is a reaction. 1 Balanced forces, 2 the forces acting on each other, and 3 the forces acting in the same time. These can be noticed when the boy and elephant is pulling the rope tied with spring scales. The measurement of forces is then equal in average”.

Pretest

Posttest

Figure 5. Examples of the Student’ Reasoning of the Newton’s 3rd Law Situation explained in the Pretest and Posttest.

In contrast, the posttest indicated that student’ performance was classified in level 2 (RL2) because he could generate his reasons to demonstrate how the situation occurred with the Newton’ 3rd Law of Motion Concept accurately. The students also explained that “results from the experiment indicated that when the boy and elephant were exerting the forces on the
rope tired with the spring scales; those forces had equal size based on the average measurement following to the Newton’s 3rd Law: in every action, it was an equal and opposite reaction”. Accordingly, this reasoning proved that the student actually had a correct understanding in science concept.

The data from the pretest and posttest, which were collected from the students’ ideas explaining about the Newton’s Laws of Motion Concepts, was divided into three components of the scientific explanation — claim, evidence, and reasoning. The student’s performances were classified into three levels (level 0, 1, and 2). The results from this method were measured in percentage as shown in Figure 6.

Figure 6. Percentages of All Components of Scientific Explanation Performance.

The percentage figures presented as the progression of the students’ scientific explanation performances after applying the GAI Model to Newton’s Laws of Motion classroom. The students actually improved their levels of performances from the pretest to the posttest at all components required, especially the percentage of the students’ performances in level 2 (the highest), higher than the results of the pretest which most of students were scored only at level 0 (the lowest).
In addition, all students’ performances were scored and followed by a rubric: level 0 (0 point), level 1 (1 point), and level 2 (2 points). A comparison results from the pretest and posttest scores were computed by using the parametric statistic: mean scores, standard deviation, and a mean was compared by using paired sample ttest. The results were analyzed as shown in Table 2.

Table 2

Comparison of Students’ Scientific Explanation Performances in the Pretest and Posttest

<table>
<thead>
<tr>
<th>Components of Scientific Explanation</th>
<th>N</th>
<th>Pretest</th>
<th>Posttest</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>x (S.D.)</td>
<td>x (S.D.)</td>
<td></td>
</tr>
<tr>
<td>Claim</td>
<td>42</td>
<td>7.76 (1.845)</td>
<td>10.81 (0.740)</td>
<td>10.194*</td>
</tr>
<tr>
<td>Evidence</td>
<td>42</td>
<td>4.83 (1.937)</td>
<td>9.69 (1.773)</td>
<td>12.425*</td>
</tr>
<tr>
<td>Reasoning</td>
<td>42</td>
<td>3.50 (1.728)</td>
<td>8.31 (2.909)</td>
<td>9.383*</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>16.09 (3.122)</td>
<td>28.81 (4.049)</td>
<td>15.240*</td>
</tr>
</tbody>
</table>

*p < 0.05

A comparison results from the pretest and posttest scores were calculated by using the parametric statistic showing that the students significantly improved their abilities to explain in each and overall components of the scientific explanations (p < 0.05). With these results, it can be confirmed that the GAI Model’s procedures could help the students develop generating and revising the scientific explanation. According to the argumentation session with the GAI Model, the students were given an opportunity to communicate and argue to their classmates for generating a scientific explanation of the phenomenon based on empirical evidences from the experiment. This stage encouraged the students to make claims by using the available data and to give reasons for describing why the situation occurred with correct scientific concepts through the argumentation (Samson & Groom, 2010). Conversely from
the first, most students had performances at the lowest level since they generated explanations only from their prior knowledge or experiences in everyday life which possibly lead to the misunderstanding and inconsistency with the situation purposes.

In addition, the two representative students who had the lowest- and highest-scores were questioned by using a semi-structured interview. Purposive collection was used in this regard to select representative student from aforementioned process because those students totally gave different answers and explanations. As shown in Table 3, the highest-score student could answer questions correctly and give examples in everyday life to support answers; moreover, he could explain reasons based on scientific principles properly which was different from the lowest-score student’ answers.

Table 3

*Students’ Answers from Semi-Structured Interview*

<table>
<thead>
<tr>
<th>Question</th>
<th>Highest-Score</th>
<th>Lowest-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the answer of the students?</td>
<td>The children and elephant exert the forces equally well.</td>
<td>The elephants exert the forces more than the children.</td>
</tr>
<tr>
<td>2. Students explain the evidence or examples to support this answer.</td>
<td>If the springs are attached to both of the ball and wall, when kicking the ball, the reader read the value of two springs and find out that they have the same values.</td>
<td>No answer</td>
</tr>
<tr>
<td>Question</td>
<td>Highest-Score</td>
<td>Lowest-Score</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3. What is the reason for that?</td>
<td>The force at which one object acts on the second object is equal to the force on which the second object acts on the first object, but in opposite directions.</td>
<td>If the object is larger, the force will be exerted greater.</td>
</tr>
</tbody>
</table>

Even though they had different answers, both groups did enjoy learning in the classroom more than the traditional way. It cannot be refused that the GAI model could help the students refine their explanations in the phenomenon as well as develop their communication and presentation skills effectively. It is more likely to say that they can become more reliable and rational persons in the near future.

**Conclusions**

In conclusion, there are many effects of the Generating Argument Instructional Model on Newton’s Laws of Motion Classroom. The investigation of this research study clearly proves that after applying the GAI Model through the argument session in the classroom, the students could significantly improve on their abilities in explaining the Newton’s Law of Motion Concept correctly and completely with three required components, viz. scientific claim, evidence, and reasoning. They were capable to do the experiment, make claims, and gather enough evidence and reasons to support their own answers properly. The communication and argumentation expressing their ideas about the reasons of how the phenomena occurred, which were shared and discussed among their classmates, were also clearer and better. Moreover, the students could develop a skill of revising and summarizing their explanations which is deemed as the core conception of the situation efficiently. Last but not least, the students were capable to refine their understandings of explaining other
situations. Therefore, this could be concluded that the Generate an Argument Instructional or GAI Model could significantly enhance the students’ abilities in generating the scientific explanation for learning scientific concepts.

**Recommendations**

Recommendations for the further research study are as follows: Firstly, an engagement scientific explanation through the Generate an Argument Instructional should be proceeded in groups. If the students discuss or argue with their classmates, they will have a variety of arguments. So that (s) the aware of the advantages or improvements in each of the components of the explanation. Secondly, teachers should prepare students for scientific argumentation prior to using the GAI’s procedures because this will allow the students to play attention in each role correctly. Thirdly, an implementation of the GAI should be applied with arguments to other instructions for increasing knowledge, ability, development of other concepts, and rationality.

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Uniqueness of Senior High School Students’ Sequence Expressions of Triangle of Representation in Electrochemistry

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Abstract
Most of scientific contents usually deal with concrete and abstract concepts. Particularly, chemistry contents require students to interconnect among three levels of representation including macroscopic, sub-microscopic, and symbolic representation respectively in order to deeply understand. However, students have encountered learning difficulty because they need multilevel thoughts. Thus, students avoid finding out explanation for both concrete and abstract contents. Previous research findings indicated that the use of concrete educational materials can effectively help students understand abstract and difficult concepts in chemistry. This study aims at investigating what and how students express the sequence of the chemical triangle (macro, sub-micro, and symbolic representation) in learning electrochemistry.

Methodology employed in this study was interpretive paradigm. Data were collected over two months by using classroom observations, interviews and students’ worksheet. The Drawing of Chemical-Electrical Representations was a worksheet which was specifically designed and used for eliciting what and how students expressed their ideas of electrochemistry through drawing and writing modes. A framework used to analyze data was based on Johnstone’s three representational levels. The finding showed that three types of students’ sequence expression of triangle of representation were clearly found. First is the concrete to abstract direction (i.e., from macroscopic to sub-microscopic and symbolic representation). Second is the abstract to concrete direction (i.e., from symbolic to sub-microscopic, and to macroscopic representation). Third is the alternating direction (i.e., from macroscopic to symbolic and sub-microscopic representation). Most students who got started at macroscopic representation first said that a scientific phenomenon from carrying out experiments was tangible and easy to observe and then record such as the change of voltmeter or the corrosion of metals. They, therefore, were able to connect these tangible phenomena to more abstractness. Interestingly, a student who was categorized in alternative direction gave her reasons that writing symbolic representation, for example chemical
equations of a redox reaction was more abstract than sub-microscopic level—the changes and occurrences of atom or molecules. However, she expressed her idea that symbol was shorter to write and it less details than drawing atomic phenomena, therefore linking symbolic with macroscopic representation was easier to make senses. These findings were consistent with a participant’s ideas which had abstract to concrete learning style. Interview revealed that symbolic phenomena helped her understand the mechanism of gain-loss electron in reduction and oxidation reactions in laboratory works. She could visualize in her minds and then recheck the actual occurrences from performing experiments, doing hands-on activities, and interacting with computer simulation technology. The different patterns of students’ sequence expression in learning electrochemistry will be useful for researchers and teachers to plan and design the better instructional strategies to respond and support the diverse needs of students appropriately.
Uniqueness of Senior High School Students’ Sequence Expressions of Triangle of Representation in Electrochemistry

Scientific phenomena in chemical perspective can be classified into three levels—macroscopic, sub-microscopic, and symbolic representations (Johnstone, 1982; 1991). This classification is often used as the triangle. Macroscopic representation can be easily observed by human five senses (hearing, sight, smell, taste, and touch). They are visible and tangible, for instance, color changes, pH changes, smell, bubbles. In addition, using tools to measure and display results (e.g., moving of a voltmeter needle when the electric potential is different) is considered as macroscopic representation. The sub-microscopic representation is the scientific phenomena which are intangible, for example atoms, molecules, and electric current. Symbolic representation is illustrated as signs such as chemical formula, chemical equation.

However, high school students have still encountered the difficulty in learning electrochemistry (Aydin, Friedrichsen, Boz, & Hanuscin, 2014; Brandriet & Bretz, 2014; Hamza, 2013; Rosenthal & Sanger, 2012; Supasorn, 2015). Although they are able to describe and explain phenomena they can observe, they have problem to interconnect among three levels of representation (Johnstone, 1991; Ramnarain & Joseph, 2012). For example, producing direct current by galvanic cell in classroom laboratory, learners have to link the electric happened by observing lamp or voltmeter (macroscopic) with the change in atomic level as electron transfer (sub-microscopic). In addition, they are also asked for illustrate their symbolic idea after finishing experiment such as writing equation in each half-cell, making direction symbol for electric current. Therefore, it is important for chemistry teachers to help them learn through connection among such three levels (Gilbert & Treagust, 2009; Ramnarain & Joseph, 2012; Taber, 2013a; 2013b; Talanquer, 2011)
Previous research studies have been applied the notion of triangle representation into chemistry instruction as teaching methods and educational materials to improve students’ learning (Adadan, 2013; Antonoglou, Charistos, & Sigalas, 2011; Gegios, Salta & Koinis, 2017; Nyachwaya & Gillaspie, 2016; Taskin, Bernholt & Parchmann, 2015). However, a problem should be concerned is that helping students interconnect among three levels of chemical representation. Even Johnstone (2000) proposes that the use of three representations with novice students should avoid getting started all with macroscopic at once. Importantly, some researchers recommend that chemical representations should be presented from the concreteness to abstractness idea. This means that macroscopic representation should be presented first since it is the most concreteness followed by the sub-microscopic and symbolic representation (Lin, Son and Rudd II, 2016). In addition, Ramnarain and Joseph (2012) suggest that teachers should use scaffolds to help students connect and translate of each representation. Thus, this study is interested to design the Drawing of Chemical-Electrical Representations worksheet as a scaffolding to support them in expressing their representation in electrochemistry. Moreover, patterns of students’ sequence expression of triangle of representation are also studied. Research questions of this study are focused on: what and how students express their sequence of the chemical triangle (macro, sub-micro, and symbolic representation) in learning electrochemistry?

Methodology

Research Design and Participants

This study was drawn from an interpretive research. Participants consisted of 81 senior high school students from two classes in Thailand –class A and B consisted of 40 and 41 students respectively. Each class contained students of mixed abilities. In teaching electrochemistry, they had not been expected to use three specific technical terms, such as macroscopic, sub-microscopic, and symbolic representation. Hence, other familiar words
which were appeared in the Drawing of Chemical-Electrical Representation (DCER) worksheet were used instead of the macro, sub-micro, and symbolic representation in order to avoid difficulty. Substitute words for macroscopic level contained metals which you can observe, changes which you can directly touch, as well as experimental results which you can detect by your five senses. Sub-microscopic level contained changes at particle or atomic level, gain-loss electrons in a reaction. Symbolic representation contained chemical equations and arrows represented flow of electron and electricity.

**Data Collection and Analysis**

Data were collected by the first author who played a role as chemistry teacher. Each electrochemistry class was taught for three periods in a week (a 50 minute period) over two months. Participants were grouped for doing an electrochemistry experiment (e.g., galvanic cell). They were provided with the DCER worksheet during experimentation. This worksheet was designed in order to help them express and elicit their own ideas through writing and drawing modes based on an idea of macro, sub-micro, and symbolic representations. Significantly, they were free to express levels of representation which they desired to present subsequently.

To respond the first research question: what sequences of the chemical triangle (macro, sub-micro, and symbolic representation) that student express in learning electrochemistry? Data were collected by a checklist questionnaire – My Sequence of Representation (MSR) after finishing class experiment. This questionnaire consisted of six items which were designed from all six possible sequences. Participants completed the questionnaire as a self-observer and were asked to choose only one sequence fitted to their personal data.

To respond the second research question: how students express their sequence of the chemical triangle (macro, sub-micro, and symbolic representation) in learning
electrochemistry? Three kinds of data sources were collected. First is a researcher’s self-reflection. Second is reflection from a critical friend, a chemistry teacher who adequately understand this research context and background. A critical friend also played roles as an observer. During teaching and learning of electrochemistry, a video recorder was also used. Third is the participants’ DCER worksheet and they were also interviewed for eliciting their ideas. Data from all three sources were analyzed by using inductive method.

Findings

Three types of students’ sequence expression of triangle of representation were found as follows. Type I: starting at macro to sub-micro to symbolic representation. This type was found most frequently. Type II: starting at symbolic to sub-micro to macro representation. Interestingly, type II was rarely found. Type III: starting at macro to symbolic to sub-micro representation. Some of the students were found in this type. More details of students’ sequence expression in each type were discussed.

Type I: Macro to Sub-micro to Symbolic Representation

Sequence of this type is the concreteness to abstractness direction. Most participants illustrated electrochemistry phenomena by this type. They constructed their content representation at macro level first. They provided their reasons that this level 1) can be directly observed by themselves, 2) can be directly recorded without interpretations, and 3) is tangible things. Some interviews can be shown as below.

TypeIstudent2: If I note others first, it makes me confused whether it is correct or wrong. So I note from my eyesight first

After completing macroscopic levels, students moved to sub-micro and then symbolic representation, respectively. They revealed their reasons that changing at atomic level is an
essential idea for writing chemical equation. In the other words, particulate representation plays a role as promoting symbolic expression as the interview below.

Researcher: Why did you do on particulate level after completing visible level? Why didn’t you do on symbolic?

TypeIstudent1: Because I would understand that which one get electrons, which one donate electrons, So I could write the symbols correctly.

Researcher: Based on your answer, is writing chemical equation is your final aim?

TypeIstudent1: Not really, I mean if I can write atoms initially, I will be able to write equation easier.

Researcher: Did you write an equation before drawing atoms?

TypeIstudent1: No, I wrote this (sub-micro) before I wrote this (symbolic). It lets me know which one was reduction, which one was oxidation, then brought it to write the equations.

According to the reflection from a critical friend, type I could promote students’ understanding in electrochemistry. The interview is shown below.

Researcher: Do you think that macro, sub-micro, and symbolic expression can promote students’ learning?

Critical friend: If I were a student who did the DCER worksheet, I think it promotes students to think. It could help students explain, in my perspective, because it emerges from sight firstly, then look inside into the unseen level, and focus on symbolic. I think this method, if I do I would get more understanding.

These data from students and a critical friend indicate that students hold something less abstract to learn more abstract. They spent time firstly at macroscopic phenomena which
were easy to observe then they interconnected to sub-microscopic which is atomic and ionic phenomena due to make understanding the particle level. Finally, they wrote chemical equations for expressing their symbolic representation, respectively.

**Type II: Symbolic to Sub-micro to Macro Representation**

Some students in this group got started learning from symbolic to sub-microscopic to macroscopic representation, in the other word they learnt from abstract to concrete expression. Symbolic was written first. Students provided their reasons that writing chemical equation could help them make whole illustration of an electrochemistry phenomenon happened in a redox reaction: consists of two half-reactions i.e. reduction and oxidation which is related to gaining and donating electrons at the same time. Writing symbolic first could utilize them to easily understand the gain-lose electrons occurrences of at a particulate level. Additionally, they indicated that symbolic representation was shorter than others levels. Lastly, symbolic expression was less details therefore it is full meaning. Some interviews are shown below.

Researcher: Why did you get started at chemical equation? Why didn’t you get started at visible?

TypeIIstudent1: If I wrote this one (symbolic), it helped me understand its working process. I wrote it separately (redox reaction) in order to make my understanding that how it happened, how it donated, how it gots, something like that. Then after finished the writing, I drew atoms that they happened for checking. Is it same as my thought?

Researcher: You said “I wrote.” Is it chemical equation?

TypeIIstudent1: Yes, I compiled in my brain to make it clear on chemical equations first, then I wrote others.
Researcher: I would like to ask you: Is there a relationship between writing chemical equation and something you can see? For example, if you write symbolic: is symbolic in macro and sub-micro?

Type II student 1: It is coherent. If I can write chemical equations, it could make me draw such as Mg^{2+}. I’m…… Based on my idea, Magnesium would corrode, if I could represent this by writing a chemical equation I could make these pictures (sub-micro, macro). Make it got relation. I have to know an equation first, then I would draw some visible things and atomic level.

Interestingly, these students’ data were consistent with to the critical friend’s reflection (i.e., indicating on his or her previous semester teaching about the importance of symbolic representation. s/he (Critical friend) said that “Acid-base in last term, I emphasized on students’ writing equation more than others.”

These findings indicate that students learnt from abstractness first and extend to concreteness. They had their perceptions regarding in electrochemistry through symbolic representation, then link to sub-microscopic expression in order to understand reaction mechanism at particulate level. Finally, they asked themselves to conclude that: is symbolic representation according to sub-microscopic and macroscopic representation which I could observe in the classroom? This question helps them to re-check with experimental results. That is, symbolic representation is used as a “Re-checking” tool for self-generating macroscopic and sub-microscopic representations. However, students did not deny that they observed at concreteness first, they merely noted and learnt at abstractness before others.

**Type III: Macro to Symbolic to Sub-micro Representation**

There were students in this group learnt in two directions; 1) concreteness to abstractness (macroscopic to symbolic), and 2) abstractness to concreteness (symbolic to sub-
microscopic - writing and drawing at macroscopic level then moved to symbolic instead of sub-microscopic. They provided reasons that linking macroscopic with symbolic representation was easier than with sub-microscopic representation. Symbolic representation could help them understand macroscopic phenomena. Findings from interview were also shown below.

Researcher: Why did you do symbolic after macro? Why didn’t you start at atom?
You can express your idea. It’s your reason.
TypeIIIsstudnet1: Yes, It (symbolic) helped me know what chemicals were separated or what chemical could coat another.
Researcher: Yeah.
TypeIIIsstudent1: Yes, I would like to assume when I do an experiment by using zinc and copper. Copper donated electrons, I know that this chemical lose electrons, which one is oxidation, which one is reduction. Then I will write down an equation. It’s easy to write.
Researcher: Does it makes you easy?
TypeIIIsstudent1: Yes, I separate first, and then I combine it later. It’s easier. It helped me know which one is right. I think.

Additionally, findings show that their ability to understand sub-microscopic representation came from a combination of symbolic and macroscopic for confirming sub-microscopic phenomena. In another word, they learnt by connecting macro to symbolic level more than connecting macro to sub-micro level. Excerpts from the interviews were shown.

Researcher: In your opinion, between symbolic as chemical equation and drawing at atomic level, which one is more difficult? Which one is easier?
TypeIIIsstudent1: I think writing symbolic is easier. Making sure by separating it, I have to know its origin first then I would combine each step (of reaction). If I’m
curious some things on its background I wouldn’t do any things. I have to study it seriously otherwise I would doubt.

Researcher: How about your term “origin” in terms of chemistry?

TypeIIIstudent1: In terms of chemistry, origin means…. Which chemicals have to…. Which one can gain an electron? Which one can lose an electron? Why does it lose an electron? Is it really happen? I could back to my first step, that is, I could see with my eyes.

Researcher: Yeah.

TypeIIstudent1: At that time, there was something coated at zinc metal. I could saw. So I wrote a symbol for checking it is true. I also asked myself that is it right? Then I moved to a particulate level later.

According to such interviews, students’ ideas and reasons found in type III are interpreted that:

1) sub-microscopic is more complicated than symbolic representation

They perceived that sub-microscopic is less abstract than symbolic representation. Although the researcher attempted to ask some of the student which one was more abstractness, they did not respond directly. They merely uncovered their view that sub-microscopic was more complicated than symbolic representations. In the other word, they indicated that writing chemical equations (symbolic) was a divided into an oxidation and reduction reaction. Whereas drawing atomic phenomena (sub-microscopic) was a produced many elements at the same time which they pointed it as more complicated. One of the students (TypeIIstudent1) said that “writing atomic level is more difficult than chemical equation. I could write an equation as one by one of a reaction (oxidation or reduction), it makes me clear what happen in each element.
2) linking macro with symbolic representation is easier than linking with sub-microscopic representation

Students in this type still got started learning with macroscopic phenomena through doing experiments. However, they revealed their sequence that linking macroscopic with symbolic representation is easier than with sub-microscopic representation. One of the students (TypeIIstudent1) said that: “In my first block of the worksheet which is visible (macro level), I have to clearly see occurrences of each element. Copper coated at zinc, it meant zinc lose electrons for copper, or copper got electrons. It means copper gains, and zinc loses electrons. So I wrote down at symbolic block of the worksheet in order to part (both reactions) obviously.”

3) sub-microscopic is the intrinsic cause of reaction

Students in this group showed a perspective on sub-microscopic representation that it is the intrinsic cause of chemical reaction, they therefore did it finally. One of the students revealed her opinions that: “According to my idea that if I doubt I would focus until I could understand. I have to clearly know on what happened before, so I specify which one happens, then I make a connection that this one gains or loses electrons. If I do atomic (sub-micro) changes before symbolic level, it let me doubts that this one comes from. I might not know source of changes…, therefore I write down at particulate level.”

**Conclusion**

It was found that senior high school students express their sequences of triangle of chemical representation in electrochemistry in different ways. Although the most sequence of students’ expression get started with the concreteness to abstractness, it is important for chemistry teacher to provide learning activities based upon their ideas. According to a previous research, the concrete to abstract representation is recommended for novice students who have just start studied electrochemistry (Lin, Son, & Rudd II, 2016). However, findings
from this study demonstrate that some students had different sequence expression of representation. This would be symbolic to sub-micro to macro representation as well as macro to symbolic to sub-micro representation. These two different patterns of students’ sequence expression in learning electrochemistry will be more concern by researchers and teachers to plan and design the better instructional strategies to respond and support the diverse needs of students appropriately. Furthermore, instruction strategies used in electrochemistry should be provided severally, for example doing an experiment or hands-on activity, the DCER worksheet class for covering all of macro, sub-micro, and symbolic phenomena.
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Assessment Literacy of Science Teachers Across Levels

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Abstract

Assessment plays an important role in teaching and learning process as it benefits both the teachers and students in number of ways. It can be considered as a significant determinant of what, when and how students learn. It is also a powerful tool in enhancing classroom instructions. In 1990, the American Federation of Teachers, the National Council on Measurement in Education, and the National Education Association have constructed the standards for teacher competence in educational assessment of students based on the concept that assessment is an integral part of instruction and the effective instruction cannot take place without good assessment of students. The seven standards assert that teachers should be skilled in (1) choosing assessment methods appropriate for instructional decisions; (2) developing assessment methods appropriate for instructional decisions; (3) administering, scoring and interpreting the results of both externally-produced and teacher-produced assessment methods; (4) using assessment result when making decisions about individual students, planning teaching, developing curriculum and school improvement; (5) developing valid pupil grading procedures which use pupil assessments; (6) communicating assessment results to students, parents, other lay audiences and other educators and; (7) recognizing unethical, illegal, and otherwise inappropriate assessment methods and uses of assessment information. To evaluate the literacy on student assessment, 30 science teachers who were teaching in the elementary, secondary, and tertiary levels were purposively sampled and surveyed using the 35-item multiple choice format of a Classroom Assessment Literacy Inventory (CALI) which was designed parallel to the Standards for Teacher Competence in the Educational Assessment of Students. The responses of the teachers were coded in two scoring schemes; binary and partial-credit using the Structure of Observed Learning Outcomes (SOLO) Framework. To determine in which area were the science teachers good in and where they needed professional support, and to explore their overall assessment literacy and its relation to their gender, educational attainment, and years of teaching experience,
mean, frequency, standard deviation, t-test, and one-way analysis of variance (ANOVA) were utilized. Results revealed that Science teachers have an overall average level (M=1.47) of assessment literacy, with low level (M=0.58) for Competency No. 6. Furthermore, results showed that there is no significant difference between scores of male and female using the binary scoring and partial scoring respectively (t=-0.223, p=0.826) (t=-0.083, p=0.935); no significant difference between the science teachers’ educational attainment and assessment literacy scores for three conditions [F(2,27)=0.346, p=0.711], [F(2,27)=0.565, p=0.575]; and no significant difference between teaching experience and assessment literacy scores [F(4,25)=0.789, p=0.543], [F(4,25)=0.465, p=0.761]. The study recommends that Science teachers are given well-developed programs that will increase their assessment literacy, especially in the area where they will develop or improve their skill in communicating assessment results to students, parents, other lay audiences, and other educators. Conduct of similar studies is also recommended, involving a larger number of science teachers and/or teachers from other areas of specialization to strengthen validity of results and contribute to improving assessment literacy of teachers across fields.
Assessment plays an important role in teaching and learning process as it benefits both teachers and students in number of ways. In fact, it can be considered as a significant determinant of what, when and how students learn. It is also a powerful tool in enhancing classroom instructions. According to Gronlund (2006), assessment refers to the process used in the classroom by teachers to obtain information about students’ performances on assessment tasks, either as a group or individually, using a variety of assessment methods to determine the extent to which students are achieving the target instructional outcomes. In this regard, classroom assessment literacy of teachers is an important factor to be considered.

A student’s learning becomes complex as it progresses. SOLO or Structure of Learning Outcome, first described by Collins (1982) is a means of classifying learning outcomes in terms of their complexity enabling a teacher to assess students’ work in terms of quality. The SOLO assesses how students pick up no aspect of a task (prestructural), only one or few aspects (unistructural), several but unrelated aspects (multistructural), integrate aspects into a whole ((relational), and generalize a whole to yet untaught application (extended abstract). A classroom teacher’s assessment literacy as stressed by Chappuis et al. (2012) is necessary both as knowledge and skill for compiling data about students’ achievement for effective utilization of the assessment process and outcomes to improve students’ achievement. However, according to Rogers (1991) classroom teachers are calling for more training due to their perceived lack of preparedness to assess their students, citing weaknesses in their undergraduate preparation programs. Kahl et al. (2012) concluded that in many pre-service programs, coverage of assessment literacy in course work and practical is incomplete and superficial leaving graduates unprepared to effectively meet the demands of today’s K+12 environment. Therefore, there is a need for teachers to continuously improve and enhance themselves in terms of assessment in order to develop quality instructions and
quality students. As what McMillan (2000) cited in Volante & Fazio (2007), teachers who have sufficient background knowledge about assessment are able to integrate testing into learning and to use instructional format that is suitable for students.

The competence of teachers is specified by standards for educational assessment of students as adopted by UNESCO. According to Ololube (2008), these standards express specific expectations for assessing knowledge or skills that teachers should possess in order to perform well in their evaluation effort. In 1990, the American Federation of Teachers, the National Council on Measurement in Education and the National Education Association have constructed the standards for teacher competence in educational assessment of students based on the concept that assessment is an integral part of instruction and the effective instruction cannot take place without good assessment of students. Such standards encompass teachers’ professional roles as well as their responsibilities for student assessment. Also, the standards represent a conceptual framework or scaffolding from which specific skills can be derived.

The seven standards are as follows: (1) Teachers should be skilled in choosing assessment methods appropriate for instructional decisions; (2) Teachers should be skilled in developing assessment methods appropriate for instructional decisions; (3) Teachers should be skilled in administering, scoring and interpreting the results of both externally-produced and teacher-produced assessment methods; (4) Teachers should be skilled in using assessment result when making decisions about individual students, planning teaching, developing curriculum and school improvement; (5) Teachers should be skilled in developing valid pupil grading procedures which use pupil assessments; (6) Teachers should be skilled in communicating assessment results to students, parents, other lay audiences and other educators and; (7) Teachers should be skilled in recognizing unethical, illegal, and otherwise inappropriate assessment methods and uses of assessment information.

In the Philippines, the assessment standards for teachers are incorporated in the National Competency Based Teaching Standards (NCBTS) and there are no specific
competencies on the rigors of classroom and educational assessment. In this regard, Magno & Gonzales (2011) stated that teachers’ level of confidence and competence in classroom assessment still need attention. Thus, the study investigated the assessment literacy of Science teachers across levels as an input to relevant professional development program on educational measurement. Specifically, it sought to answer the following questions:

1. What is the level of assessment literacy of sampled Science teachers in the following areas of competence in student assessment?
   a. Choosing assessment methods appropriate for instructional decisions
   b. Developing assessment methods appropriate for instructional decisions
   c. Administering, scoring and interpreting the results of both externally produced and teacher-produced assessment methods
   d. Using assessment result when making decisions about individual students, planning teaching, developing curriculum and school improvement;
   e. Developing valid pupil grading procedures which use pupil assessments
   f. Communicating assessment results to students, parents, other lay audience and other educators.
   g. Recognizing unethical, illegal, and otherwise inappropriate assessment methods and uses of assessment information

2. Is there a difference in the level of assessment literacy of the Science teachers when they were grouped according to the following?
   a. Gender
   b. Educational attainment
   c. Years of teaching experience
Methods

Descriptive research design was employed in the study. The study aimed to determine the assessment literacy of science teachers from different school grade levels and explored its relation to their gender, educational attainment, and years of teaching experience.

Study Sample

The participants who completed the questionnaire were 30 purposively selected science teachers who were teaching junior high school to tertiary levels. Among the participants, 53% were female while 47% were male. Most of the participants or 77%, graduated with a Master’s Degree while in terms of teaching experience, 47% had been teaching for 6-10 years, 20% for 1-5 years and 11-15 years and only 13% had a teaching experience for 16-20 years.

Instrument

The research instrument used was adapted from the Classroom Assessment Literacy Inventory or CALI, modified by Mertler (2003, n.d.). The instrument was further modified by experts in the field from a nationally recognized Teacher Education Institution (TEI) to suit the context. The inventory consists of two parts. Part I consists of 35 items parallel to the seven “Standards for Teacher Competence in the Educational Assessment of Students”. Some of the items are intended to measure general concepts related to testing and assessment, including the use of assessment activities for assigning the student grades and communicating the results of assessment to students and parents; other items are related to knowledge of standardized testing and the remaining items are related to classroom assessment. Part II consists of items related to the background of the participant as a classroom teacher.
Data Collection

After securing the necessary permit and consent to participate, the 4-page CALI was administered to the participants in their preferred time and place but within one semester of school year 2016-2017. The scores were then tallied and interpreted according to the CALI Manual.

Data Analysis

Data were analyzed by means of descriptive statistics such as mean, frequency, standard deviation, t-test and one-way Analysis of Variance (ANOVA). The Structure of Observed Learning Outcomes (SOLO) Framework is used to describe how proficient or competent a teacher in the standards being tested and provide needed professional growth. Using SOLO, the responses of the teacher participants were coded in two scoring schemes; binary and partial-credit. The binary scoring was used to describe how proficient or competent the science teachers in the competency being tested. While the partial scoring was used to describe the level of competence the science teachers are to inform a more relevant or needs-based development plan to help them get higher in their level of understanding. The codes used follow the stages in the SOLO taxonomy and these were as follow: 0- pre-structural, 1- uni-structural, 2- multi-structural, and 3- relational. Using the binary score, the code 3- means High proficient and 0- means low proficiency level.

Results and Discussion

The level of proficiency of Science teachers was determined using the codes in the SOLO framework. Figure 1 below shows the level of assessment literacy of Science teachers in the seven areas of competence in student assessment.
As shown in Figure 1, Science teachers have a frequency score on the following competencies: C1 (1.9), C2 (1.66), C3 (1.48), C4 (1.38), C5 (1.66), C6 (0.58) and; C7 (1.6). This means that science teachers have low (1.49 and below) proficiency level in C3 - Administering, scoring and interpreting the results of both externally-produced and teacher-produced assessment methods, C4- using assessment result when making decisions about individual students, planning teaching, developing curriculum and school improvement and C6, that is communicating assessment results to students, parents, other lay audience and other educators. While C1- Choosing assessment methods appropriate for instructional decisions, C2 - Developing assessment methods appropriate for instructional decisions and C7 - Recognizing unethical, illegal, and otherwise inappropriate assessment methods and uses of assessment information, science teachers have high proficiency level.

Figure 2 shows the level of competence where Science teachers are good, and where they were weak at and in which they could be given appropriate development program.
Based on the figure, the Science teachers are good at C1 - Choosing assessment methods appropriate for instructional decisions, C2 - Developing assessment methods appropriate for instructional decisions, C5 - Using assessment result when making decisions about individual students, planning teaching, developing curriculum and school improvement and C7 - Recognizing unethical, illegal, and otherwise inappropriate assessment methods and uses of assessment information. However, C6 - Communicating assessment results to students, parents, other lay audience and other educators, C3 - Administering, scoring and interpreting the results of both externally-produced and teacher-produced assessment methods and C4 - Using assessment result when making decisions about individual students, planning teaching, developing curriculum and school where the areas of competency needs to be prioritized in designing professional programs to help teachers in terms of assessing students’ learning outcomes.

The level of competence of Science teachers was also explored when they were grouped according to their gender, educational attainment and teaching experience using the two scoring scheme. In Table 1, using binary scores for gender, results showed that there is
no significant difference between Male scores (M = 49.15, SD = 10.43) and Female (F = 49.94, SD = 8.93, condition; t (28) = -.223, p = .826.

Table 1

Independent Samples t-Test on Gender (Binary Scores)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Male</td>
<td>49.15</td>
<td>10.43</td>
<td>-.223</td>
<td>28</td>
<td>.826</td>
</tr>
<tr>
<td>b. Female</td>
<td>49.94</td>
<td>8.93</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: *n = 35, *p < 0.05

Table 2, using the partial scores results for Gender, showed that there is no significant difference between Male scores (M = 61.46, SD = 16.90) and Female (F = 61.00, SD = 13.62, condition; t (28) = -.083, p = .935

Table 2

Independent Samples t-Test on Gender (Partial Scores)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Male</td>
<td>61.46</td>
<td>16.90</td>
<td>.083</td>
<td>28</td>
<td>.935</td>
</tr>
<tr>
<td>b. Female</td>
<td>61.00</td>
<td>13.62</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows the binary scores result on educational attainment. The result showed there is no significant difference between the educational attainment and scores assessment literacy of science teachers at the p < .05 level for the three conditions [F (2, 27) = .346, p = .711]
Table 3

ANOVA Between Assessment Literacy and Educational Attainment (Binary Scores)

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>64.575</td>
<td>2</td>
<td>32.288</td>
<td>.346</td>
<td>.711</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2522.625</td>
<td>27</td>
<td>93.431</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2587.200</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4, using the partial scores results for educational attainment, showed that there is no significant difference between educational attainment and the scores on assessment literacy of science teachers at the p < .05 level for the three conditions [F (2, 27) = .565, p = .575]

Table 4

ANOVA Between Assessment Literacy and Educational Attainment (Partial Scores)

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>256.800</td>
<td>2</td>
<td>128.4000</td>
<td>.565</td>
<td>.575</td>
</tr>
<tr>
<td>Within Groups</td>
<td>6138.000</td>
<td>27</td>
<td>227.333</td>
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<tr>
<td>Total</td>
<td>6394.800</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5, using the binary scores results for teaching experience, showed that there is no significant difference between teaching experience and the scores on assessment literacy of science teachers at the p < .05 level for the three conditions [F (4, 25) = .789, p = .543]
Table 5

*ANOVA Between Assessment Literacy and Years of Teaching Experience (Binary Scores)*

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>289.950</td>
<td>4</td>
<td>72.488</td>
<td>.789</td>
<td>.543</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2297.250</td>
<td>25</td>
<td>91.890</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2587.200</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6, using the partial scores for result for years of teaching experience, showed that there is no significant difference between teaching experience and the scores on assessment literacy of science teachers at the p < .05 level for the three conditions [F (4, 25) = .465, p = .761]

Table 6

*ANOVA Between Assessment Literacy and Years of Teaching Experience (Partial Scores)*

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>443.050</td>
<td>4</td>
<td>110.762</td>
<td>.465</td>
<td>.761</td>
</tr>
<tr>
<td>Within Groups</td>
<td>5951.750</td>
<td>25</td>
<td>238.070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6394.800</td>
<td>29</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Conclusion and Recommendation**

Assessing students’ learning outcomes is one of the most critical roles teachers inside the classroom. The results of assessments administered to students can either positively or negatively affect their overall performance. This study was carried out to determine the assessment literacy of Science teachers across levels. The results revealed that Science teachers have an average level of assessment literacy except for Competency No. 6, i.e. communicating assessment results to students, parents, other lay audience and other educators. It is therefore recommended that the Science teachers are given well-developed
programs that will strengthen their overall assessment literacy, especially in the area where they will develop or improve their skill in communicating assessment results to students, parents, other lay audiences and other educators. Conduct of similar studies is also recommended, using teachers from other areas of specialization and/or other variables which may also contribute to higher level of assessment literacy.
References


Development of Game-based Science Simulation for Promoting Elementary School Students’
Learning in Plant Growth

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Abstract

Over the past few decades, digital technologies and learning resources have important roles in education, and recent research found that the digital technologies can effectively support teachers’ teaching practices in integrating inquiry-based instruction into science class. Moreover, regarding rapid growth of learning technology in science, game-based simulation is an effective digital media for enhancing science teaching and learning through the combination of computer simulation and digital game. This learning technology could promote students’ motivation and attitude as well as increase their comprehensive understanding of science concepts. As such, the researchers have developed a visual-aid learning technology of game-based simulation representing plant growth experiment and then implemented with 32 of 4th grade students in a public elementary school located in northeastern region of Thailand. This paper illustrated the proposed game-based simulation as innovative learning tool with guided inquiry learning, for promoting students’ science learning in elementary school. Moreover, the paper presents an investigation of affective channel result on students’ perception and attitude towards the guided-inquiry science learning with a support of the proposed game-based simulation. The elementary school students were assigned to interact with the proposed simulation regarding guided-inquiry learning process within two weeks for one lesson. After finished the lesson, they were administered 21-items and 20-items perception and attitude questionnaire, respectively. The results showed that they expressed positive perceptions and attitudes towards the guided-inquiry learning experience employing game-based simulation. This indicated that the use of game-based simulation as an inquiry learning tool with the facilitation of teacher is an interesting way for promoting the learning of science experimentation for new-generation learners in 21st century education era. The main implication of this study is the development of novel learning tool addressing science concept of plants growth for promoting students’ science learning performance in elementary school science.
Development of Game-based Science Simulation for Promoting Elementary School Students’ Learning in Plant Growth

**Background**

In Thai compulsory education curriculum, children in the elementary grades are exposed to and build understandings of biological concepts through their interactions with the world around them. Plant growth is an important topic in elementary school science. Plants are the connection between the sun and energy flow on earth and it is difficult phenomena for students learning due to its complex conditions and the emergence of various misconceptions about plant. When considering what plants need to grow, ideas can become even more complicated for elementary school students (Barman et al., 2003). Tunnicliffè and Reiss (2000) have found that student understanding of plants and what plants need to grow is often limited. Moreover, Barman et al. (2006) found that misconceptions about plants and plant growth are introduced and reinforced at early ages. For example, students will often ascribe that plants need food in much the same way that people need food. Additionally, student misconceptions arise is in their conflation of ideas around what plant needs are provided by people (e.g., house plants, gardens) as opposed to what plants receive from their environment (Barman et al., 2006). Because plant growth play an important role in the science education standards and frameworks in Thai compulsory education curriculum, it is important to understand how to facilitate and assist students to learn effectively about plant growth.

Over the past few decades, digital technologies and learning resources have important roles in education (Dorji, Panjaburee, & Srisawasdi, 2015; Lee & Chen, 2009), and recent research found that the digital technologies can effectively support teachers’ teaching practices in integrating inquiry-based instruction into science class (Meesuk & Srisawasdi, 2014; Nantakeaw & Srisawasdi, 2014). Due to features of technology, the support of students’ visualization and imagination skill is important for science learning in school
science level. Also, technological tools could promote learning motivation and inspiration for students. Educational researchers mentioned that implementing technology-based learning environment could raise students’ cognitive engagement and learning performance (Srisawasdi & Panjaburee, 2015; Kanyaprasit & Srisawasdi, 2014). Regarding rapid growth of digital learning technology in science, game-based simulation is an effective digital media for enhancing science teaching and learning through the combination of computer-simulated experiment and digital game. It is known that the learning with game-based simulation approach has great potential for facilitating the engagement of students in science learning activities. This learning technology could promote students’ motivation and attitude as well as increase their comprehensive understanding of science concepts (Udomrat & Srisawasdi, 2015; Ruttanasaeng, Srisawadi, & Kanjak, 2015). Moreover, with recently, digital games have been becoming popular and integral part of our society, especially children or younger generation who like to play game as a favorite activity (Lokayut & Srisawasdi, 2015).

According to the above mentioned, the purpose of this study was to develop a visual-aid learning technology of game-based simulation representing plant growth experiment as innovative learning tool with guided inquiry learning, for promoting students’ science learning in elementary school.

**Previous Studies on Game-like and Simulation-based Learning in Science**

Nowadays, information technologies have changed rapidly. Digital learning becomes a learning trend, because it can record students’ learning situation on the learning system and help teachers to understand and manage students’ learning portfolio. Owing to the rapid development of digital technology, digital games and simulation are popular now. In recent years, a combination of digital game and simulation, shortly called game-based simulation, for learning has become an important research topic in educational research and development. Now there are many researchers and scholars advocate to develop digital game-
based simulation for promoting favorable and positive learning and enhancing the better learning competency for students. By the game-based simulation learning, we can live up to educate children while having fun with them at the same time and increase their learning achievement (Meesuk & Srisawasdi, 2014; Ruttanasaeng, Srisawadi, & Kanjak, 2015).

Computer simulations, which contain visualization and features for representing a high abstract thing, can help student adjust variable in simulation and observe phenomenon (Chen-Chung Liu, 2011). These features have been recognized as an effective tool for teaching and learning method in science (Khan 2011; Wellington 2004). As such, computer simulation can be effective instructional practices in promoting science content knowledge, developing process skills (Smetana & Bell, 2012) and promoting students’ perceptions of learning (Kamtoom & Srisawasdi, 2014). Interactive computer simulations allow learners to conduct virtual experiments that cannot easily be conducted in real-life situations (Chang, 2016). Learners can change the parameters and values of the simulation to test their hypotheses and theories. For the benefit features of digital game is challenge, rewarding and enjoyment (Meesuk & Srisawasdi, 2014; Papastergiou, 2009). Researchers revealed that digital game-like learning could promote students’ interest, motivation, attitude, and enhance conceptual learning outcome (Lokayut & Srisawasdi, 2014; Nantakaew & Srisawasdi, 2014). According to both feature above, game-based simulation is an effective digital media for enhancing science teaching and learning through the combination of computer simulation and digital game. This learning technology could promote students’ motivation and attitude as well as increase their comprehensive understanding of science concepts (Udomrat & Srisawasdi, 2015; Ruttanasaeng, Srisawadi, & Kanjak, 2015).

**An Overview of the Game-based Simulation on Plant Growth**

In this study, the researchers have developed a visual-aid learning technology of game-based simulation representing plant growth experiment. The game-based simulation
has been developed to use as an android mobile application for mobile devices, both smartphones and tablets. The application used for the study, Smart Farm, is briefly introduced here. The game was designed by the authors and implemented in Unity 3D with the assistance of a software developer. It is a role-playing game that aims to engage elementary school students in science learning of plant growth. The main scenario of the simulation is related to smart farming emphasizing how to grow plant in an indoor garden environment. The player takes on the role of a smart farmer (the main character in the game-based simulation). The player must know the goal of the game-based simulation (i.e., to evaluate all of the factors of a plant growth) and what rules to follow, which can be found at any time in the main scene of the simulation.

With the use of the proposed game-based simulation as an inquiry tool to conduct scientific experiment in a smart farm, players can control their own learning from playing the simulation representing plant growth experiment by (1) adjusting a number of variables in the experiment, (2) observing the phenomena, and (3) investigating how the plant growth based on their own experiment. In addition, the players can have a physical activity by using a smartphone or tablet to read QR code from several cards for adding target variables in the plant growth experiment. Figure 1 shows example of the game-based science simulation.
Figure 1. Screen illustration of the game-based simulation on plant growth experiment: main screen of the simulation (left); experimental space in the simulation (middle); an example of the game card (right).

In this game-based simulation, it was divided into four series regarding the factors of plant growth. The main factors of plant growth included soil, water, light, and gas. In this simulation, students have to play and pass each series in a sequence. Student can get score and it depends on the accuracy of the experimental results. After completing the experiment with the game-based simulation, students were interacted with a worksheet.

Methods

Methods and Research Instruments

This research divided into two studies. For the first one, this study used a survey method to investigation of affective channel result on students’ perception and attitude towards the guided-inquiry science learning with a support of the proposed game-based simulation. This study used two instruments for evaluating the elementary school students’ perceptions and attitudes toward the proposed game-based simulation. The perception questionnaire consisted of 21 5-points rating scale items (Peng et al., 2009) that focused on two perceptual constructs consisting; (i) learning experience (12 items) and (ii) overall impression (9 items), with a perfect score of 60 and 45 points, respectively. Another, the attitude questionnaire consisted of 20 5-points rating scale items (Barkatsas, Kasimatis, & Gialamas, 2009) that focused on five constructs consisting; scientific confidence (SC), attitude to learning science with technology (ST), confidence with technology (TC), affective engagement (AE), and behavioural engagement (BE), which each dimension has four items and the perfect score is 100. The Thai version of these instrument has been developed by Chaipidech and Srisawasdi (2016) and Premthaisong and Srisawasdi (2016) by the
translation-back translation method. For each item, respondents were assigned to rate how much the respondent agree with into five scales, ranging from 1-strongly disagree to 5-strongly agree. Validity and reliability had established the instrument.

For the study two, this study was investigation on students’ conceptual understanding towards the guided-inquiry science learning with a support of the proposed game-based simulation. After completing the experiment, they were asked to complete conceptual understanding of plant growth by a two-tire question item test. A pre-experimental research method regarding one group pretest-posttest was used for the study. The collected quantitative data were analyzed by using descriptive statistics. i.e. arithmetic mean, standard deviation, frequency, percentage and t-test.

**Participants**

The participant of this study included 32 of fourth-grade students, aged between 9 - 10 years old, in a local public elementary school located at northeastern region of Thailand. They were 11 boys and 21 girls from similar economic background, and they all have basic skills in using smartphone and tablet PC.

**Data Collection and Analysis**

The procedure of study one, before the interaction with the game-based simulation representing of plant growth, teacher provided an introduction of plant growth concepts and the procedure for investigation in the simulation for 40 minutes. Then students were conducted an experiment by their own investigation for 50 minutes. After learning by participating with the simulation activity, all students were administered and took both questionnaires of perception and attitude for 30 minutes, as illustrate in Figure 2.
For the study two, this study was investigation on students’ conceptual understanding towards the guided-inquiry science learning with a support of the proposed game-based simulation. The students were assigned to 30-minutes pretest before performing the game-based simulation experiment of plant growth. Then students were exposed to interact with a guided-inquiry science learning with a support of game-based simulation representing plant growth experiment for 50 minutes. After completing the experiment, they were asked to complete conceptual understanding of plant growth by a two-tire question item test, as illustrates in Figure 3.
Results

In this study, the results have been reported into three dependent variables as follows, from both studies.

Students’ Perceptions with the Game-based Science Simulation (Study One)

The result from the perception questionnaire covering two subscales, including learning experiences and overall impressions, shows that they perceived positively on the learning experiences (89.40%) and overall impressions (90.10%) of the game-based science simulation. Figure 4 shows percentage of the elementary school students’ perceptions toward the science lessons.
Figure 4. Percentages of the elementary school students’ perceptions.

In order to explore more in-depth data of their perceptions, some of the students have been interviewed individually and the qualitative results were as follows. The result reveals that they have favorable perceptions with the game-based science simulation.

“Basically, I like science subject and I love to conduct the experiment activity. With conducting the science experiment in game-like simulation, it made me collecting data with the experiment easily. Moreover, I like the way it allows me to try and adjust variables in the experiment and I can know the result immediately.” (A female student)

“With the use of game-like simulation to conducting the experiment activity, it is better way for me to observe phenomena of plant growth which influenced by adjust variables, so it made me more interesting in science learning class, because I can understand the lesson from doing the experiment by myself, so it caused to me more self-confidence to do the experiment next time.” (Another female student)
Students’ Attitude Towards the Guided Inquiry Lessons with the Game-based Science Simulation (Study One)

To explore elementary school students’ attitude towards the game-based guided inquiry lessons, the attitudes questionnaire covering five subscales, i.e. scientific confidence (SC), attitude to learning science with technology (ST), confidence with technology (TC), affective engagement (AE), and behavioral engagement (BE) has been administered to the students, and the result shows a different level of their attitudes on each subscale. The highest score was relied on ST (91.25%), SC (89.85%), BE (89.5%), TC (89.05%), and AE (87.95%), respectively, as illustrates in Figure 5.

Figure 5. Percentages of the elementary school students’ attitude.
According to the individual interview, some of interview data reflected the elementary school students’ attitude towards the guided-inquiry lesson with game-based simulation of plant growth. Some evidences of their attitudes could be illustrated as follows.

“I love to learn science by doing the experiment in the simulation. It was very fun, and I can finish the experiment faster than conventional experiment. Normally I love to play the game every day, then from doing the experiment in this simulation, it made me understand the lesson easily. Moreover, I can teach my friends who cannot understand how to play the game-like simulation, it made me proud.” (A male student)

“I love to do the experiment in science subject like this (game-like simulation), because it made me fun and challenge as I was playing a game. While I was doing the experiment, I felt a challenge to do a learning competition with my friend, in order to be the winner, and we don’t need to worry about dangerous from chemical substances. Also, it made the science learning class to be no boring.” (A female student)

In a conclusion, both results from the study one reported the preliminary results and it showed that they expressed positive perceptions and attitudes towards the guided-inquiry learning experience employing game-based simulation.

**Students’ Conceptual Understanding on Plant Growth (Study Two)**

To examine the influence of guided-inquiry learning with game-based simulation in this study, a comparison between pre- and post-test conceptual understanding scores has been performed to reflect its influence on elementary school students’ learning. The comparative results of pre- and post-test showed that students showed a significant different on their conceptual understanding of plant growth score. The posttest mean score (Mean = 15.53, S.D.
= 6.36) was higher significantly different than the pretest mean score (Mean = 8.72, S.D. = 1.41) at the level of 0.05, as shows in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Conceptual understanding</th>
<th>No. of student</th>
<th>Total score</th>
<th>Mean ($\bar{X}$)</th>
<th>S.D.</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>32</td>
<td>21</td>
<td>8.72</td>
<td>1.41</td>
<td>0.00*</td>
</tr>
<tr>
<td>Posttest</td>
<td>32</td>
<td>21</td>
<td>15.53</td>
<td>6.36</td>
<td></td>
</tr>
</tbody>
</table>

Note: * significant difference at .05 (p<0.05)

Based on the paired t-test analysis, the results indicated that the students, who had participated in the guide-inquiry learning with game-based simulation have better conceptual understanding scores than before the participation. In other words, after the instruction (using guided-inquiry learning with game-based simulation), the elementary school students had enhanced their scientific understanding of plant growth phenomena. This indicated that guided-inquiry learning with game-based simulation had a significant impact on the development of conceptual understanding in science. Therefore, this method has been shown to be superior to the learning approach of science concept in elementary school level.

**Conclusion**

The study reported that, this visual-aid game-based simulation addressing science concept of plants growth with guided inquiry learning instruction could promote students’ science learning performance in elementary school. Moreover, the study found that they expressed positive perceptions and attitudes towards the guided inquiry learning experience employing game-based simulation. This indicated that the use of game-based simulation as an inquiry learning tool with the facilitation of teacher is an interesting way for promoting the
learning of science experimentation for new-generation learners in 21st century education era.

In the future, we will improve the guided-inquiry learning with game-based simulation based on the above research results. Moreover, we will carry out experimental teaching to explore the impact of human factors on the game-based simulation learning, and also conducting a well-design experimental research in order to investigate its impact on elementary school students’ science learning.
References


A Strong Daily Terminology Influence Biology Learning: Biological Classification as a Case Example

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Abstract

The concept of animal classification is one of the most misconceived concepts in high school biology. This is often caused by everyday terminology conflicting with scientific conception. This research aims to explore science conceptual understanding of concepts relating to animal classification of high school students. The misconceptions found were used to design an inquiry-based teaching and learning activity for enhancing scientific conceptions. The research was conducted as 2 phases; survey of scientific misconceptions and teaching and learning implementation, respectively. One hundred and ninety of 11th graders were participated in the first phase and thirty-five of 11th graders were participated in the second phase, respectively. The research tools were as follows: 1) twenty-one test items for scientific conceptions of animal kingdom as a survey instruments, 2) inductive inquiry teaching and learning activities of animal kingdom using animal found in the country. Tools used to collect data were validate before implementing. Collected data were analyzed qualitatively using descriptive statistic.

The results indicated that some students (23.19%) held were the result of terminology used in daily life. They misunderstood a turtle to be an amphibian (34.29%), an earthworm a reptile (45.71%), etc. After implementing teaching and learning activities, some students (3.54%) had a better understanding of all concepts of scientific animal classification. However, some students (15.71%) still had scientific misconceptions, e.g. seahorse is water-living thing, dolphin and squid are a fish, crocodile and turtle are amphibians, earthworms as reptiles, butterfly and bat are aves, penguin as mammals etc. It was found that the characteristics of those animal weren’t not easy for students to observe and classify them into the group. Existing classification was still brought into the use, consequently the misconceptions were remained.

This suggests that conceptions of animal classification held by students are strongly influence by every day experience. This also suggests that students perhaps come to the classroom with
their own system of classification. So, uncovering their systematics is perhaps required before implementing the lesson.

*Keywords:* Scientific conceptions, Animal classification, Inductive inquiry, High school biology, Scientific Misconceptions
A Strong Daily Terminology Influence Biology Learning: Biological Classification as a Case Example

Students enter in science classroom with varying experience with their own conceptions about the world. Some conceptions are correct and some are alter from a scientific consensus. The conceptual idea that differs from the commonly accepted scientific views as alternative conceptions or misconceptions (Garnett & Treagust, 1990). There are several factors that affect learning e.g. teachers (adequacy in professional knowledge, teaching style, attitude), students (ability, attitude, learning styles, motivational styles), assessment methods, and socio-cultural factors etc. (Bahar, 2003) Misconceptions is also an important factor impediment learning.

A common misconceptions in biology are found from students across the world. A large number of prior studies reported that many students held misconceptions in basic biology topics such as cellular structure and function (Marek, 1986), acellular and multicellular, cell division, osmosis and diffusion, photosynthesis, molecular genetics (Fisher, 1985), aerobic and anaerobic respiration, digestion and excretion (Barass, 1984), ecological concepts (Adeniyi, 1985), human anatomy and physiology, plant and animal classification (Trowbridge and Mintez, 1985), evolutionary theory and living-nonliving (Tamir et al., 1981).

Regarding misconceptions mentioned above, plant and animal classification are the concepts that student can easily bring their daily experience into the classroom. Students need to know how living things are classified for better understanding its biodiversity. Animal classification and biodiversity is also very important for providing a true understanding of many biology contents (Randler, 2008). Trowbridge and Mintzes (1988) suggested that alternative conceptions about classification may negatively impact learning of higher-order concepts such as ecology and evolution.
Animal classification is one of the most misconceived concepts in high school biology. This is often caused by everyday terminology conflicting with scientific nomenclature. For example, starfish and jellyfish are often believed to be fish (Trowbridge and Mintzes, 1998). Students tend to classify animals using criteria such as movement, appendages (leg or legless) and habitat, rather characteristics of those in animal kingdom. These criteria can lead students to classify some animals incorrectly. For example, snakes were classified as invertebrates because they lack obvious limbs, mammals such as whales as fish because their habitat is in the water (Carey, 1985). The turtle and crocodile are classified as an amphibian due to its aquatic and terrestrial habits (Yen et al, 2004). Many Students often classify animals by its status (organisms that fly, organisms that live in the water or land) based on observable features. It becomes challenging when they have to use a taxonomic classification system to group animals. Some of those characteristics might not be able to observe.

One of the key elements of science teaching is helping students apply their scientific conceptual understanding to explain nature. In order to promote efficient and meaningful, inquiry-based education as allows students to achieve a conceptual change leading to the scientifically correct ideas. Inductive reasoning are characterized as constructivist methods. Learning is an active process. Allowing students to form the ideas on their minds from observable and fact freely. This will help them make an inference, construct their concept, by themselves.

This research aims that explore students’ scientific conceptual understanding of animal classification of high school biology. We’re also applying inductive inquiry using organisms found in the country to stimulate and promote students’ learning by themselves.
Purpose of the Study

This research aims to explore students' understanding of concepts relating to animal classification and implement inductive teaching and learning activity to promote scientific conceptions of animal classification.

Methodology

Participants

A total of 190 students studying eleven-grade classrooms at secondary school and who have selected biology as core subject were selected as a participant to survey their scientific conception. While a thirty-five student of a selected classroom was used to implement an inductive-inquiry teaching and learning. Research was conducted between August, 2017 and September, 2017.

Data Collection

The research tools were as follows:

1) Twenty-one test items as a survey instruments for scientific conceptions of animal classification.

The items were true-false test with its reasoning. The test items were developed to investigate in the following areas; characteristic of organisms and animal classifications. Concepts and some of its test items were shown in Table 1.
Table 1

Example of concepts of animal classification test items

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Example of test items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept 1 Classifications of organisms</td>
<td>1. bacteria are classified as animals</td>
</tr>
<tr>
<td></td>
<td>2. Whale as a fish</td>
</tr>
<tr>
<td></td>
<td>3. Penguin as mammals</td>
</tr>
<tr>
<td>Concept 2 Kingdom Animalia (classifications of animal; vertebrates and Invertebrates)</td>
<td>What’s the difference between Invertebrate and Vertebrate?.</td>
</tr>
<tr>
<td>Concept 3 Vertebrates (characteristic of vertebrates)</td>
<td>Draw organisms are classified as fish (Pisces)</td>
</tr>
<tr>
<td></td>
<td>Giving a definition and a diverse list of fish.</td>
</tr>
</tbody>
</table>

2) An Inductive inquiry activity.

The activity of inductive inquiry of each lesson was shown in Table 2. Each activity was compiled to the Basic Education Core Curriculum B.E. 2551 (A.D. 2008) of Thailand,
Table 2
The Descriptions of each inductive inquiry activity of animal classification

<table>
<thead>
<tr>
<th>Activity</th>
<th>Concepts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Classifications of organisms</td>
<td>Pictures of bacteria, protozoa, micro-organisms, fungi, plants and animals were shown, students were inquired to observe and make an inference of classifications of organisms into five kingdoms.</td>
</tr>
<tr>
<td>2</td>
<td>Kingdom Animalia (classifications of animal; Vertebrates and Invertebrates)</td>
<td>Example of fish, shrimp and shell were provided for inquisitive exploration and hands-on learning and the classification task required student to categorize each animal into 2 major groups, invertebrates and vertebrates. Pictures of animals such as, starfish, frog, snake, eel, earthworm, worm, butterfly and insect were shown and question were asked about the classification of animals, students were inquired to observe and make an inference of a concept of Vertebrates and Invertebrates.</td>
</tr>
<tr>
<td>3</td>
<td>Vertebrates (characteristic of vertebrates)</td>
<td>Given a pictures of shark, whale, dolphin, bat, bird, turtle, frog to compare the difference between turtle and frog, butterfly and bird, bat and bird. Students were also asked to draw and write a definition of fish, amphibians, reptiles, birds, and mammals.</td>
</tr>
</tbody>
</table>

3) Open-ended questions:
Free response of drawing method was used to access students’ scientific conceptual understanding. An example of the question was shown in Fig. 1.

![Figure 1. Show an example of open-end question](image)

**Analysis**

The true-false test and free-response answers were analyzed by categorizing the respondents into 5 groups of scientific conceptual understanding: scientific understanding (SU), partial understanding (PU), partial understanding with specific misunderstanding (PU/SM), scientific misunderstanding (SM) and no understanding (NU). Descriptive statistics was used to explain the data. Detail of the groups were as follows in Table 3, 4.
Table 3

*The rubric of true/false question*

<table>
<thead>
<tr>
<th>Groups</th>
<th>Answer the True/False question</th>
<th>Supporting ideas (evidence/examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SU</td>
<td>Correct response</td>
<td>Answer is clear and student provides several specific examples to help support their answer.</td>
</tr>
<tr>
<td>PU</td>
<td>Correct response</td>
<td>Student provides some specific evidence/examples for their answer, but additional examples are needed.</td>
</tr>
<tr>
<td>PU/SM</td>
<td>Correct response</td>
<td>Student provides some specific evidence/examples for their answer are incorrect.</td>
</tr>
<tr>
<td>SM</td>
<td>Incorrect response</td>
<td>Student provides some specific evidence/examples for their answer are incorrect.</td>
</tr>
<tr>
<td>NU</td>
<td>None response</td>
<td>Student replied, “I don’t know” or no response was given to the statement.</td>
</tr>
</tbody>
</table>
Table 4

The rubric of open-ended questions

<table>
<thead>
<tr>
<th>Groups</th>
<th>Answer</th>
<th>Drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>SU</td>
<td>Answer is clear and student provides several specific examples to help support their answer.</td>
<td>Connection to Drawing and answer is clear.</td>
</tr>
<tr>
<td>PU</td>
<td>Student provides some specific evidence/examples for their answer, but additional examples are needed.</td>
<td>Connection to Drawing and answer is not clear.</td>
</tr>
<tr>
<td>PU/SM</td>
<td>Student provides some specific evidence/examples for their answer, but additional examples are needed.</td>
<td>Drawings are not used to help organize the ideas for the concept.</td>
</tr>
<tr>
<td>SM</td>
<td>Student provides some specific evidence/examples for their answer are incorrect.</td>
<td>Drawings are not used to help organize the ideas for the concept.</td>
</tr>
<tr>
<td>NU</td>
<td>Student replied, “I don’t know” or no response was given to the statement.</td>
<td>No drawing</td>
</tr>
</tbody>
</table>

Results and Discussion

1) Students’ misconceptions of animal classification.

The data from true or false survey instrument found out that students most students are misconceived of animal classification. The misconceptions are shown in Table 5.
Table 5

Misconception of 11th graders on animal classification

<table>
<thead>
<tr>
<th>Concept</th>
<th>Misconception</th>
<th>Types of Misconceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Classifications of organisms</td>
<td>-Paramecium and Amoeba are classified as animals (40.00)*</td>
<td>Preconceived notions</td>
</tr>
<tr>
<td></td>
<td>-Turtle as amphibians (17.14)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Earthworms as reptiles (42.86)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Bats as aves (11.43)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Penguin as mammals (20.00)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Dolphin as fish/Pisces (5.71)*</td>
<td>Vernacular misconception</td>
</tr>
<tr>
<td></td>
<td>-Squid as fish (17.14)*</td>
<td></td>
</tr>
<tr>
<td>2. Kingdom Animalia (classifications of animal; vertebrates and Invertebrates)</td>
<td>-Snake is an invertebrate (5.71)*</td>
<td>Preconceived notions</td>
</tr>
<tr>
<td>3. Vertebrates (characteristic of vertebrates)</td>
<td>-Turtle as amphibians (2.86)*</td>
<td>Preconceived notions</td>
</tr>
</tbody>
</table>

Note: (*) Percentages of students that held Persistent Misconceptions.

From Table 5, it was shown that most misconceptions regarding animal classification were classified as preconceived notions (National research council, 1997). Students' responses were analyzed and classified into 5 groups by their level of understanding: scientific understanding (SU), partial understanding (PU), partial understanding with specific misunderstanding (PU/SM), scientific misunderstanding (SM) and no understanding (NU).
The results of this research are summarized in Table 6 in Appendix indicated that most of students had partial understanding (40.95%); scientific misunderstanding (23.19%) and no understanding (19.05%) of the conception of scientific animal kingdom before studying. However, students had a better understanding of all concepts (3.54%) of scientific animal classification after studying and the most of students had partial understanding (68.03%). However, the study found that even after instruction some students still had scientific misconceptions (11.97%). This study shown the responses of the students were as follows the concepts of classifications of organisms, Kingdom Animalia and Vertebrata.

**Students’ Understanding about Classification of Organisms**

![Graph](image)

*Figure 2. The percentages (%) of the responses relevant to classification of the organisms.*

The conceptions were categorized into five groups (see figure 2). Overall, a high percentage of students’ understanding about classification of organisms were partial understanding (43.24%); no understanding (24.76%). In the concept of classifications of kingdom Protista and kingdom Monera, most students had specific misunderstanding (29.99%) before studying. For example, they misunderstood bacteria are classified as animals. The reasons quoted by students were, it’s the simplest animals, it’s single-celled...
animals; Cyanobacteria are classified as animals because it’s bacteria which is an animal, Cyanobacteria as Protista; Algae are both classified as Plantae and Animalia; Paramecium and Amoeba are classified as animals, a group of flattened animals, it’s Monera; dolphins are classified as fish because they live in the water; their body are cold blooded, Turtle as amphibians; it lays eggs, breathe with lungs, earthworms as reptiles; it is insects; roundworms; move slowly, Butterfly as aves; it has wings; penguins as mammals; they feed their young with milk. After studying, students had a better understanding of all concepts (3.54%) of scientific organism classifications. However, the study found that even after instruction some students still had scientific misconceptions (15.71%). And the persistent misconception were Paramecium and Amoeba are classified as animals, Earthworms as reptiles, Crocodile and turtle as amphibians, Penguin as mammals etc. (See table 5).

**Students’ Understanding about Classification of Animals**

![Figure 3](image-url)

*Figure 3. The percentages (%) of the responses relevant to classification of invertebrates and vertebrates.*

The Figure 3 was about the biology concept, “classification of the animals” into two major groups, vertebrates and invertebrates. Students were asked to classify the animal as a
vertebrate or an invertebrate. A high percentage of students’ understanding were partial understanding (65.71%). For instance, the semi scientific reasons cited by students were, it’s strong and its shape possess presence of a vertebral column. Some students gave more complicated reason to identify the vertebrate animals, it has tail; nerve cord; notochord. The major groups include fish, amphibians, reptiles, birds and mammals recognized it as a vertebrate. However, the students show misconceptions while describing the reason to identify the animals as a vertebrate, it can sit; stand up, it has a skeleton etc. at the same time students quoted that invertebrate don’t have backbone; a soft-bodied organism; slow moving; creeping. As mentioned above, some students classified snakes as an invertebrate. They describe that snake is very winding, no backbones and they can’t stand upright. Similarly, tortoise was also classified as an invertebrate. They describe the characteristics of tortoise as a soft body animal with hood. Moreover, 2.86% students gave no reason except to quote the words ‘I think vertebrate it is vertebrate’. As misconceptions mentioned above it is shown that students maintain their preconceive notions even after the instruction.

Students’ Understanding about Characteristic of Vertebrates

![Graph showing percentages of students' understanding](image)

*Figure 4. The percentages (%) of the responses relevant to classification of the vertebrates.*
The finding from students’ answer to the question of classification of characteristic of vertebrates following concepts: fish, amphibian, reptile, bird, and mammal in Figure 4 showed that most of students had partial understanding with a specific misconception (60.00%; PU/SM); partial understanding (29.14%); scientific misunderstanding (5.71%) and no understanding (5.14%) of the conception of characteristic of vertebrates before studying. However, students had a better understanding of all concepts (4.00%) and 0.57% students of scientific misunderstanding after studying. In order to probe students’ understanding of vertebrate animals. Student were asked to identify the animals by drawings (the drawings depict a fish, amphibian, reptile, bird, and mammal) and the answers given by the students to the open question were studied. Some of the drawings supporting the misconceptions. The most misconceptions was the characteristics of the amphibians and reptiles. The students were asked to draw the picture of amphibians. Most students identify turtle in this group, while the most common reason given by most students to explain why it is an amphibian was because it lives in both aquatic and terrestrial habitats. Besides, the majority of students identified whale as a fish and giving the reason they look like fish (Fig. 5). Some students categorize all aquatic organisms as fish. They draw fish as represent as in a cartoon, rather fish as of scientific concept. While, some student had misconceptions about Aves. They perceive bat, butterfly and bee are Aves due to its wings and ability to fly. Furthermore, penguins also was classified as mammals by many students.
Conclusion

The results of this research indicated that most of students (19.05%) had no understanding of the conception of scientific animal kingdom before studying. Misconceptions that some students held were the result of terminology or preconceive in their daily life. For example, they misunderstood a turtle to be an amphibian, an earthworm a reptile, etc. Students had a better understanding of all concepts (3.54%) of scientific animal classification after studying. However, the study found that even after instruction some students still had scientific misconceptions (15.71%) in Table 5. Persistent misconception were seahorse are not classified as a fish, dolphin as a fish, squid as a fish, crocodile as amphibians, turtle as amphibians earthworms as reptiles, butterfly as aves, bats as aves, penguin as mammals etc.

This suggests that conceptions held by students as a result of every day experience have a strong influence on learning about scientific animal classification. This also suggests that students perhaps come to the classroom with their own system of classification. However, inductive approach stimulates and promotes students learning by themselves. The results of this study will benefit teaching and learning important biological concepts.
Acknowledgments

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References


The Study of Students’ Understanding in Nature of Science

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Abstract

Nowadays the nature of science (NOS) is one of a main goal in science teaching and learning. This study aims to examine the student understandings in nature of science (NOS) of 43 grades 10th students in Mahasarakham, Thailand. The purposive sampling was use to select the sample. the test consists of 8 open-ended questions about NOS that develop from Lederman and group covering 6 aspects of NOS; 1) a definition of science, 2) scientific process, 3) tentativeness of scientific knowledge, 4) creativity and imagination in science, 5) laws and theories, and 6) influence of society and cultures on scientific knowledge was used as a study tool. Data were analyzed by content analysis which divided into 3 groups; complete understanding, partial understandings and misunderstandings. The result indicated that a majority of student 62.46 percent held complete understandings in aspects of a definition of science. But most of students saw partial understandings in the aspects of scientific process and influence of society and culture on scientific knowledge about 80.34 and 79.12 percent respectively. Moreover, it found that 94.52,96.72 and 88.78 percent of student also have misunderstandings in scientific laws and theories, tentativeness of scientific knowledge, as well as creativity and imagination in science respectively. the study finding suggested that science teachers should focus and find proper teaching methods integrated NOS into the activities or instructions for developing students’ understandings of NOS and promoting students to be scientifically literate persons.

Keywords: Nature of Science, Tentativeness of Scientific Knowledge, Scientific process
The Study of Students’ Understanding in Nature of Science

Nature of Science (NOS) is one of the main goals in learning and teaching science in classroom. Because understanding in NOS can improve students to be the Scientific Literate Person which is the ultimate goal of learning science (Lederman 1992; McComas and Olson 1998; Yuenyong and Narjaikaew, 2009). The view of NOS aspect has been interested from a group of NOS philosopher and science education in the last decade. Moreover, the science education group in many countries try to integrate the understanding of NOS for student in classroom which is contain in curriculum of science subject and science teacher standard. For example, in the United states have Organization call American Association for the Advancement of Science (AAAS) (1989) which develop curriculum for benchmarks for Scientific Literacy. The main objective of these benchmarks specified that the understanding in NOS play roll important of teaching science. In addition, in Thailand national NOS issue was packed into the main target of curriculum in many years. Although no agreement exists for a specific definition of NOS, there are some characteristics of the scientific enterprise (Lederman, 2007) that are derived from the way scientific knowledge is developed and that are also accessible and relevant to students’ everyday lives (Abd-El-Khalick, Bell, & Lederman, 1998). These aspects have been emphasized in recent reform documents (American Association for the Advancement of science, 1993; National Research Council, 1996) and include understanding that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of natural world), subjective (influenced by scientists’ background and experiences), partly the product of human imagination and creativity (involves invention of explanations), socially and culturally embedded, the distinctions between observations and inferences (scientific knowledge is partly a function of each), and the relationships between scientific theories and laws.

Moreover, a previous research from Thailand and other countries indicated that
student who understand in views of NOS aspect also got advantage for leaning in many ways. For instant a knowledge of NOS aspect helped student to earned understanding the knowledge of science and the process to find a new knowledge either general knowledge or scientific knowledge (Huann-Shyang Lin and Houn-Lin Chiu, 2004, Ladachart, 2012). Beside the understanding in NOS aspect can lead student to be a person who can searching for knowledge by themselves or crate new knowledge. Moreover, student who understand the limitation of science and effect of science and technology on society will be a person that can use the knowledge in the right way (Lederman, 1992). However, teaching and learning in classroom of school in Thailand teacher sill teach science subject by explain and did not focus on process for searching knowledge in science also aspect of NOS (Ladachart, 2013). This teaching method leading student misunderstand about process to inquiry knowledge of science by themselves and misunderstand about NOS aspect. In addition, from many research in Thailand increasing interests about view of NOS of student (Orawan, 2014, Pimpiran 2010, Ladachart, 2012). The research concentrated on teaching method to improve the understanding NOS aspect of student, but the studies of understand NOS aspect in student still have slightly research in Thailand. Therefore, the main goal of this research focus on study understanding of NOS aspect to add more information to improve aspect of NOS in classroom teaching and learning science subject. Furthermore, the result of this study has showed the view point of student understanding in NOS aspect which will help teacher to prepare teaching method that improve understanding in NOS of student.

**Objective**

This aim of this study is to examine the student understandings nature of science (NOS) of 43 grades 10 students in Mahasarakham, Thailand.
Method

In order to obtain intensive data, the descriptive research was used in this study which study in a small group of students in one class. The purposive sampling was use to select the sample because in senior high school student still have a few studies of their understanding in NOS.

Instruments

The Questionnaire of test consists of 8 open-ended questions about NOS that develop from Views of Nature of Science Form C (VNOS-C) Lederman and group (2002) covering 6 aspects of NOS; 1) definition of science this aspect tell about science knowledge that try to understand a matter ,phenomena in nature including universe (Lederman 1992 ; Akerson and Donnelly, 2008) .Moreover ,the aspect of 2) scientific process is about way that the knowledge is gathered (Faikhama 2013). 3) tentativeness of scientific knowledge this view point was held that the knowledge of science is not absolute truth which can change if new knowledge can explain more comprehensive than older knowledge (Haidar 1999; Lederman 1992). Moreover 4) creativity and imagination in science also see as relate to each other. Furthermore 5) laws and theories held as difference duty to explain knowledge in science. The last one is about 6) influence of society and cultures on scientific knowledge was used as a study tool. Moreover, the content validity of test was checked by 3 experts which the IOC (index of Item-Objective Congruence) was 1.0.

Data Analysis

The answer of the studies question, only qualitative analysis was possible. Due to the small sample size, it was not possible to statistically compare the effectiveness of the two approaches on students' understanding of NOS. The analyze of content was based on interpretive of researcher. Answer sheet of test were coded 1-43 which correspond to number
of student. Next read the answer in each question and coding symbol for the similar answer. The researcher saw that the answer of question agreeable Lederman and group analysis (2002). Therefore, in this study the data were analyzed by content analysis which divided into 3 groups; 1) complete understanding which understand consistent with science educator, 2) partial understandings which understand agreeable with science educator but can not give reason or explain the question and 3) misunderstandings which mean misunderstand in view of NOS with science educator. For validity of data the researcher read question and interpret information. Then dived into the group that have been set. The reliability of data the information was analyzed 2 time. After analyze first time leave data for 1 week after that analyzed again. Result saw that the difference of analyze about 20 percent.

**Result**

The overview result from 6 aspects of NOS indicated that a majority of student held misunderstanding at 54 percent. Moreover, student saw partial understanding about 35 percent. Finally, a little ratio of student about 11 percent were complete understanding and for more detail the pie chart and bar graph was illustrated below.
Figure 1. The percentage of student understanding in NOS.

Figure 2. The number of student understanding in 6 aspects of NOS.
The bar graph showed that peak of first three group of misunderstanding was 3 aspect which is about tentativeness of scientific knowledge, laws and theories and creativity and imagination in science. Furthermore, the first second aspect that student held partial understanding about influence of society and cultures on scientific knowledge and scientific process which is arrange in ascending order. In addition, there was only one aspect that the group of complete understanding greater than other group of understanding which is the aspect of definition of science.

**Definition of Science Knowledge**

The definition in this aspect many participants held understanding at 62.46 percent. Beside in the group of misunderstanding and partial understanding also was found about 30.92 and 6.59 percent respectively. For student in the group of complete understanding who can explain that science is a field that try to understand phenomena in nature and science must give evidence to prove the knowledge which make science difference with other. For example

“science is a field that try to study thing in nature which can find the truth by evidence and reason in science to support. Moreover, this field is difference with believe and religious that give knowledge part by generation.” (S13)

In addition, student who in the group of partial understanding most of them ignore the important of scientific knowledge which is the way that science knowledge is gathered. Such as

“definition of science is a subject that study about nature and explain phenomena that occur in nature.” (S18)

Finally, in group of misunderstanding they saw this aspect that
“science is an absolute truth of nature which is not relate to imagine to understand it.”

(S27)

**Scientific Process**

The science process most of student held partial understanding about 80.34 percent also 14.03 and 5.63 percent in the group of misunderstanding and complete understanding respectively. For student who in the group of partial understanding answered that

“scientific process is an activity that have done in a laboratory which is a process that try to find an answer that researcher interest.” (S22)

For student who got misunderstanding in this aspect answer that scientific process is a way to gather knowledge and step of experiment is fixed scientists must follow the step of experiment which cannot break it. Furthermore, in this aspect consisted 2 questions to affirm their understanding. The result indicated that 91.39 percent of student held partial understanding and 6.83 and 1.78 percent were misunderstanding and complete understanding respectively. For student that held complete understanding answer that

“scientific process is an activity to find the answer and the step of experiment is not fixed.” (S22)

**Tentativeness of Scientific Knowledge**

The aspect of tentativeness of scientific knowledge indicated that 96.72 percent and 2.06 percent saw partial understanding and 1.22 percent was complete understanding. For instant student that in a group of partial understanding answer that

“the knowledge of scientific can change if it gets a new experiment that can verify the knowledge and scientist accept.” (S3)
Creativity and Imagination in Science

The aspect of creativity and imagination in science was consisted 2 questions for measure the understanding of NOS. These two questions have same trend which most of student held misunderstanding about 88.78 and 90.01 percent and the group of partial understanding got 9.73 and 8.59 percent also the last group complete understanding saw 1.49 and 1.40 percent. For example, the answer of partial understanding said that

“scientist confidence that the atomic structure got characteristic like that because the evidence from laboratory.” (S32)

The student that got misunderstanding often held that atomic structure come from the shooting particle to element in laboratory.

“they think like that because evidence from laboratory that did not come from their mind such as the experiment of atomic radiation through plate gold.” (S18)

Laws and Theories

The result of aspect laws and theories found that 94.52 percent got misunderstanding and 4.27 percent experience partial understanding also saw 1.21 percent in the group of complete understanding. For instant in most of misunderstanding answer that

“law in science cannot be changed and the theories of science come from experiment which can be change.” (S21)

Influence of Society and Cultures on Scientific Knowledge

Result of this aspect was 79.12 percent about partial understanding and 10.76 percent held misunderstanding and the last one about 10.12 percent. For example, student who got misunderstanding said that
“science does not relate to society cultures because science knowledge comes from experiment and conclude to a theories or law.” (S7)

Conclusion and Discussion

The result study indicated that most of student held misunderstanding also partial understanding in all aspect of NOS. Moreover, the first three of aspect that got misunderstanding about tentativeness of scientific knowledge also laws and theories and creativity and imagination in science which is consistent with a previous study (Haidar, 1999; Lederman, 1992). Student saw that laws are important than theories and they think laws cannot be changed, they think this way might be because the method that teacher teach them in classroom which does not teach about how difference between laws and theories. Moreover, in tentativeness of scientific knowledge student also held misunderstanding most. It mean student does not understand that knowledge of science can be changed which might be because of they were educated in classroom just about content of science. Besides, in aspect of creativity and imagination in science also peak about misunderstanding which mean that student think scientist only use conclusion that based on fact which does not relate to creativity and imagination. Therefore, analyze from the result it might be because the method that use in classroom which does not teach NOS explicit enough (Schwartz, Lederman and Crawford, 2004) to explain what is experiment or how scientist gather knowledge of science, but most of teaching method just teach them to do experiment and think they will understand by themselves.

Furthermore, from the result illustrated that students got partial understanding most in the aspect of influence of society and cultures on scientific knowledge and scientific process. The first that peak in this group was scientific process, which means that student held understand about scientific process that got pattern to gather knowledge and does not know the process of science that occur from question and notice. Therefore, it might be because of
teaching method in classroom that give them just about content of science. Moreover, the also in aspect of influence of society and cultures on scientific knowledge student also held partial understanding in this aspect which consistence with the previous research (Faikhamta, 2013) which might be because in classroom does not discuss about how culture and society relate to science.

Finally, a remarkable result showed that the majority of student saw a complete understanding in the aspect of definition of science that might be because the teaching method in classroom that teacher teach by lecture to know about content and demonstrate some example to practice their skill.

Acknowledgement

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References


The Study of Students' Achievement Motivation in Physics

Peeradon Onsee, Kanyarat Cojorn, Kanyarat Sonsupap and Somsong Sitti

Mahasarakham University
Abstract

The research aimed to study the achievement motivation of Matayomsuksa 4 student. The purposive sampling was use to select the sample. The sample was 38 students of Matayomsuksa 4 in high school located on the North East of Thailand included 12 male and 26 female. The research instrument was 22 items of questionnaire which divided to 4 aspects, including aspects of decisiveness, responsibility, eagerness, and prediction. The content validity of questionnaire was examined using IOC (Index of Item-Objective Congruence) by 3 expert which was 0.88. The obtained data were analyzed in order to study the mean values of the students' achievement motivation.

The results of the achievement motivation were revealed as follows 2.72, 3.32, 2.85, and 3.04 out of 5 for aspects of decisiveness, responsibility, eagerness, and prediction, respectively. The interpretation of this data in all aspects displays in the medium level category. Based on the findings, the minimal aspect was the aspects of decisiveness. Therefore, increasing of students' achievement motivation, especially in aspects of decisiveness, of Matayomsuksa 4/3 in Phadungnaree School should be improved.

Keywords: achievement motivation, questionnaires
The Study of Students’ Achievement Motivation in Physics

In Thailand, Physics was taught as science subject for Matayomsuksa 3 and continues to the class for high school as Physics subject. Physics was one of the most important subject in sciences and can explain a lot physical phenomena in nature. According to the abstract content and a lot of mathematically based, most of students consider Physics as a difficult and impenetrable subject. Most of high schools students have to study Physics because it is a required subject in the curriculum. However, only the few students select Physics as their major to continue their bachelor degree (Hongsa-Ngiam, A. 2006). The reason might come from their motivation achievement in Physics classroom.

The success of Physics learning is influenced by various factors, one of which is the motivation (Sulistijo, S. H, 2017). The achievement motivation was studied by a lot of psychologist such as D. McClelland (McClelland, 1953), J. Atkinson (Atkinson, 1960) etc. A lot of research has been conduct since then. D. McClelland was one of the most expert in this field. The achievement motivation was define as a desire of student to working as best as possible to achieve personal fulfillment in themselves and do not want a social respect or prestige. The student who have a high achievement motivation might be successful in learning.

Methodology

This study was descriptive research using quantitative design to survey the students’ achievement motivation in Physics and analyze of data gathered. The methodology was separated in to four stages in this research namely Participant, Data Collection Instruments, Data Gathering and Data Analysis.

Participants of this research were a 38 students of Matayomsuksa 4/3 in high school located on the North East of Thailand included 12 male and 26 female.
The data collection instruments of this research was a questionnaire with 22 items. To establishing the data collection instruments, the researcher used numerous approaches of data collection to establish the questionnaire. At first, the questionnaire was contained a 25 items then it was adjusted to be 22 items after the validity of the questionnaire was checked by three experts using IOC which the mean of IOC was 0.88 out of 1 and the full data was shown in table 1.

Table 1.

Index of Item-Objective Congruence of the questionnaire

<table>
<thead>
<tr>
<th>Item’s number</th>
<th>Point from expert number 1</th>
<th>Point from expert number 2</th>
<th>Point from expert number 3</th>
<th>Mean</th>
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</table>
The questionnaire was made to gather the data of students’ achievement motivation in this research. The achievement motivation was divided into 4 aspect including 1) Aspects of decisiveness which define as a brave of student to do everything to get to the achievements. The student who have decisiveness can also make their own decision on a difficult work and know their ability to choses a work to do. 2) Aspects of responsibility define as a behavior of student that can charge their work assignments and need to get a feedback of their work in order to improve themselves. 3) Aspects of eagerness which define as a patient and empathize of student to do their work assignments and to study. And 4) Aspects of prediction which define as a behavior of student that design their own study plan. The plan was create to get a goal that they are expecting in. The questionnaire consisted of 22 items which was divided to 4 aspects of achievement motivation as above, including, 4 items, 6 items, 6 items and 6 items for aspects of decisiveness, responsibility, eagerness, and prediction, respectively.

To gather the data, the questionnaire was given to 38 student to finish the questions in their classroom without timing. During the procedure, there are a few student that finished their questionnaire very fast but most of them questionnaire were finished in about 10 minutes.

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<td>22</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.66</td>
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</table>

0.88
The data from questionnaire were analyst using simple statistic which is mean value of the students’ achievement motivation in each aspect one by one in order to shows the minimum and minimal mean value in each and compared with other.

**Results**

The data that gathered from questionnaire were analyzed in order to study the mean values of the students’ achievement motivation. The mean values of achievement motivation were 2.72, 3.32, 2.85, and 3.04 out of 5 for aspects of decisiveness, responsibility, eagerness, and prediction, respectively.

The results of the achievement motivation were revealed as follows. The minimal aspect was the aspects of decisiveness which was 2.72 out of 5. When considering each item, the question that have the lowest average value was the item number 4 “I always want to do the difficult and challenge work more than the simple work”, which has only 2.24 out of 5. The whole data of this aspect shown in table 2.

<table>
<thead>
<tr>
<th>Number of item in aspects of decisiveness</th>
<th>The mean value of achievement motivation in aspects of decisiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.29</td>
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<tr>
<td>2</td>
<td>3.43</td>
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<tr>
<td>3</td>
<td>2.91</td>
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<tr>
<td>4</td>
<td>2.24</td>
</tr>
<tr>
<td>Mean</td>
<td>2.72</td>
</tr>
</tbody>
</table>
The highest aspect was the aspects of responsibility with the mean values of 3.32 out of 5. The question in this aspect that have the most average value was item number 5 in the questionnaire “I will improve myself when I failed my exam”, which was 4.05 out of 5. The whole data of this aspect has shown in table 3. However, even this aspect have a maximum in mean values but there still have some item with the mean below 3.00, which was items 9 “I want to finish my work assignment for get to my own purpose not for social respect or prestige”.

Table 3.

Data of achievement motivation in aspects of responsibility

<table>
<thead>
<tr>
<th>Number of item in aspects of responsibility</th>
<th>The mean value of achievement motivation in aspects of responsibility</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>4.05</td>
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<tr>
<td>6</td>
<td>3.48</td>
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<tr>
<td>7</td>
<td>3.40</td>
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<td>8</td>
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<tr>
<td>9</td>
<td>2.70</td>
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<tr>
<td>10</td>
<td>3.02</td>
</tr>
<tr>
<td>Mean</td>
<td>3.32</td>
</tr>
</tbody>
</table>

The rest aspects were aspects of eagerness, and prediction, which have a mean values as follows, 2.85 and 3.04 out of 5, respectively. The question in aspect of eagerness that have the most average value was number 11 “I will continues and finish my work assignment even the environment surround me was not appropriate”, which was 3.40 out of 5 and the question that have the least average value was item number 14 “I will pay attention to my work
especially on the hardest one” which was 2.18 out of 5. The whole data of this aspect has shown in table 4.

Table 4.
Data of achievement motivation in aspects of eagerness

<table>
<thead>
<tr>
<th>Number of item in aspects of responsibility</th>
<th>The mean value of achievement motivation in aspects of responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>3.40</td>
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<tr>
<td>12</td>
<td>2.67</td>
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<td>13</td>
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<td>14</td>
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<td>15</td>
<td>2.72</td>
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<tr>
<td>16</td>
<td>2.89</td>
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<tr>
<td>Mean</td>
<td>2.85</td>
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</table>

The question in aspect of prediction that have the most average value was number 17 “I am intended to get a good grade before I graduated from high school”, which was 3.45 out of 5. The question that have the least average value was item number 21 “I always put a reading plan into my schedule and actually finish the books I want to read on schedule” which was 2.18 out of 5 as shown in table 5.
Table 5.

Data of achievement motivation in aspects of prediction

<table>
<thead>
<tr>
<th>Number of item in aspects of responsibility</th>
<th>The mean value of achievement motivation in aspects of responsibility</th>
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<tbody>
<tr>
<td>17</td>
<td>3.45</td>
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<tr>
<td>18</td>
<td>3.21</td>
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<tr>
<td>19</td>
<td>3.02</td>
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<td>20</td>
<td>3.10</td>
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<td>21</td>
<td>2.56</td>
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<tr>
<td>22</td>
<td>2.86</td>
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<tr>
<td>Mean</td>
<td>3.04</td>
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</tbody>
</table>

Conclusion and Discussions

38 students of Matayomsuksa 4 in high school, located on the North East of Thailand included 12 male and 26 female, has been studied to find their achievement motivation. The achievement motivation has been studied using 22 items of questionnaire with checked by 3 expert and have a 0.88 in ICO. The achievement motivation was divided to 4 aspects, including aspects of decisiveness, responsibility, eagerness, and prediction. The obtained data were analyzed in order to study the mean values of the students' achievement motivation. The results of the achievement motivation were revealed as follows 2.72, 3.32, 2.85, and 3.04 out of 5 for aspects of decisiveness, responsibility, eagerness, and prediction, respectively.

In aspect of decisiveness, the mean value of the students' achievement motivation was the minimal when it was compared to other. This results indicated that they might have a problem with their decisiveness such as the confident to answer the questions when they was ask by a teacher and they did not want the challenge and difficult work as an assignments.
The result also shows that in this aspect the lowest mean score is come from item 4 which the question is “I always want to do the difficult and challenge work more than the simple work”. Therefore, this result shows that the most of student like to do the simple work more than the challenge work the reason might be because they do not have the confident to do or they are afraid of failure.

In aspect of responsibility, the results shown the maximum of mean values of the students' achievement motivation. This result indicated that the achievement motivation of this aspect was the aspect that student have the most. It also was the only one aspect that has a mean value more than 3.25. The question in this aspect that have the most average value was item number 5 in the questionnaire “I will improve myself when I failed my exam”, which mean that the student are care about their own grade and they will find the way to get better. However, even this aspect have the maximum mean values but there still have one item that has a mean value below 3.00, which was items 9 “I want to finish my work assignment for get to my own purpose not for social respect or prestige”. This result indicated that the most of student want to get improved or get a better grade but not for their own purpose.

In aspect of eagerness, the question in aspect of eagerness that have the most average value was number 11 “I will continues and finish my work assignment even the environment surround me was not appropriate”. This result in this aspect shows that the most of student have some passion to finish their work and the reason might be to get a good grade. The question that have the least average value was item number 14 “I will pay attention to my work especially on the hardest one”. This information can tell us that most of student like to do the simple work more than the challenge work which is corresponding to the aspect of decisiveness.

In aspect of prediction, the results shows that most of student are paying attention on their grade before they will graduated from high school. The least average mean value was
shown in the question item number 21 “I always put a reading plan into my schedule and actually finish the books I want to read on schedule” which was 2.18 out of 5.

Based on the findings, the mean value of all 4 aspects were shows only in the medium level category that mean the achievement motivation of these Matayomsuksa 4 student are quiet low and it might cause a problem to success in Physics class because the students who shown the high achievement motivation will have much change to reach to their goal (Tella, 2007). The lowest achievement motivation was found in the aspect of decisiveness. The student who have a low achievement motivation in this aspect will not have a confident to engage in class. Therefore, the increasing students' achievement motivation of Matayomsuksa 4/3, especially in aspects of decisiveness, should be improved because of the above reason.

Acknowledgement

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