STEM education program: manufacturing mixture of phosphate and potash fertilizer straws and waste of animal bones

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Abstract. STEM educational orientation program is one interdisciplinary approaching way during study which consists of academic terms with principle characteristics combines with lectures in real life. Joining in STEM educational orientation program, students will have practical experience, thus they have opportunities to develop their capabilities including ability to apply knowledge and skills (AAK&S), help students to improve study skills and methods such as planning, analyzing, summarizing information, suggest creative solutions; encourage motivation, benefits and study activities. Based on the foundation of utilizing STEM educational orientation program in teaching, it can be a direction to develop student’s capabilities. In this study, the author instructed students to research “Manufacturing mixture of phosphate and potash fertilizer from straws and waste of animal bones” following STEM educational orientation program in improving abilities and applying Chemistry knowledge to life for the student. The result shows STEM system could handle the theoretical weight situation, help students shape and develop core competencies, specialized Chemistry and especially, the ability to apply knowledge and skills in a systematic and solid manner.

Keywords: STEM, mixture of phosphate and potash fertilizer, straws, waste of animal bones

1. Introduction

There are many concerning with the STEM education in shaping innovation and development. This push the policy of many countries continues under the orientation of STEM education [8]. However, there are three consensus issues of discussion about STEM education including (a) instructionally (b) as a set of integrated or interconnected disciplines, or (c) as more dependent on the stakeholders or context in which it is viewed or conceptualized. For this study, we will hold Moore et.al. [7] definition of STEM education for enhancing teachers. They define it as “the teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies.” To them, five characteristics distinguish integrated STEM instruction from other
teacher pedagogy: (a) the content and practices of one or more anchor science and mathematics disciplines define some of the primary learning goals; (b) the integrator is the engineering practices and engineering design of technologies as the context; (c) the engineering design or engineering practices related to relevant technologies requires the use of scientific and mathematical concepts through design justification; (d) the development of 21st century skills is emphasized; and (e) the context of instruction requires solving a real-world problem or task through teamwork. This conceptualization of STEM is grounded in learning research [12].

STEM education appeared in Vietnam a few years ago. It has just been the stage of announcement and experimental. It has not been an official education activity in high school. However, STEM education with the tasks of providing crucial knowledge and skills for students in 21st Century will become a widespread education model in the future [6]. Therefore, STEM education is highly needed the concern and awareness of the whole society.

STEM is the integration of Science, Technology, Engineering and Mathematics with real life situations, close and attractive to the learner and they need to explain, analyze, argue or conduct experiments, build models to solve problems. On the other hand, the current demand for jobs related in the STEM fields is growing and the skills of the 21st century workers also require much of the related skills that STEM education can provide. Therefore, the use of STEM educational orientation program in teaching at high schools could bring good effects and meet the requirements of society [8]; [1]. Thus, how to organize STEM activities so that students can develop the most effective their ability to apply knowledge and skills (AAK&S)?

Considering the issues of environmental pollution and human being, the applying chemical knowledge and others in everyday life is needed for people. In the recent years, a large of straws after harvesting is burned indiscriminately causing environmental pollution and many potential risks for human being. Moreover, a number of animal bones from restaurants are dropped to environment as solid waste causing polluted environment. However, if the waste is treated thoroughly, it could bring high economic benefits and also reduce environmental pollution. With “Manufacturing mixture of phosphate and potash fertilizer from straws and waste of animal bones”, it could develop AAK&S for students, create confidence, excitement for them and improve effectiveness in studying, meet the target of innovating teaching methods and improving the quality of education. As suggestions of literature review [6], [9], [10], the manifestations of AAK&S were mentioned about (1) be creative in dealing with practical issues, (2) understanding of practical problems and applying chemical knowledge to solve practical problems, (3) finding out the content of chemical knowledge is applied in real life, (4) analyzing and summarizing chemical knowledge, and (5) systematizing knowledge, classifying chemical knowledge.

In addition, this helps students familiarize themselves with the research planning, process design. Students may have chance to design the process with a lot of advantages. These included, for examples; (1) the method of using straws to break bones that saves time, electricity and cost, (2) manufacturing mixture of phosphate and potash fertilizer with %P2O5 = 33,62% and %K2O = 36,8%, and (3) low cost of fertilizer. On the other hand, the greatest significances of compound fertilizer made from straws and waste of animal bones included (1) providing nutrition for plants to achieve high productivity and good quality, (2) adding nutrients to the soil, improving soil fertility, contributing to soil improvement, and (3) reducing the risk of environmental pollution (http://binhdien.com 2018) [3’][4].

Regarding on manufacturing Mixture of Phosphate and potash fertilizer straws and waste of animal bones, it could provide students chance to apply STEM knowledge for their developing AAK&S. Therefore, STEM education intervention of manufacturing mixture of phosphate and potash fertilizer straws and waste of animal bones may develop AAK&S of students as well as other abilities such as
solving problem skill, cooperation skill, creativeness, and experiment skill. Students may analyze the current situation and environmental impacts of burning straws and directly leaving unprocessed animal bones into environment from restaurants. From that, it could build the idea to utilize those wastes because straws contain potassium, animal bones contain calcium and phosphorus, and also suggest using straws and wastes of animal bones to produce mixture of phosphate and potash fertilizer [5], [11].

2. Methodology
Methodology regarded experimental design in order to evaluate ability to apply knowledge and skills (AAK&S) of high school students through STEM activities.

2.1. Target group
In order to evaluate ability to apply knowledge and skills (AAK&S) of high school students through STEM activities, the authors carried out “the STEM education intervention of manufacturing mixture of phosphate and potash fertilizer straws and waste of animal bones” on two groups of student, each group has 10 people at Ly Nhan High School- Ha Nam Province. The experiment time took more than 3 months from March 10\textsuperscript{th}, 2018 to June 28\textsuperscript{th}, 2018.

2.2 Methods of Inquiry
According to development objectives for students (including ability to apply knowledge and skills), the author made initial observations: STEM activities could develop ability to apply knowledge and skills of readers. From that, the author built the survey to find out difficulties and also actual demands of students about STEM educational activities.

The author developed a system of STEM activities and proposed the process of organizing these activities with the target of developing abilities to apply knowledge and skills for students. The effect of the impact will be measured on the measurement scale of ability to apply knowledge and skills in solving problems of students with assigned tasks. Analyzing the impact will help the author answer the question: Is it possible to develop ability to apply knowledge and skills of students through STEM activities? How should STEM activities be organized to the best development of students' ability to apply knowledge and skills?

With the number of students taking part in at the same time, the author also found it difficult to monitor and evaluate the development of each student's ability to apply knowledge and skills. Therefore, the author conducted pedagogical experiments with the students volunteering to participate under the agreement of the school and parents. For the most accurate evaluation ability to apply knowledge and skills of each student, the author combined the combined the assessment through the survey, peer review and self-assessment. To evaluate the effectiveness of each group, the authors based on the results of analysis of fertilizer samples, experimental results on plants and product cost. Especially, in order to check the survey, the author recorded the whole process they worked and discussed.

2.3 STEM education intervention of manufacturing mixture of phosphate and potash fertilizer straws and waste of animal bones
Topic of “Manufacturing mixture of phosphate and potash fertilizer from straws and waste of animal bones” is one expended theme of STEM. After giving the production process, students have to proceed the fertilizer and then analyze the content of nutritional elements N, P in fertilizer, evaluate the quality of fertilizer, count the price and do the experiment on plants. Analysis of fertilizer samples is expensive and experiments on plants take time and effort, thus, the author found it very difficult to
organize the whole class to participate in activities that the group had designed. This intervention aimed to develop AAK&S of students as well as other abilities such as solving problem skill, cooperation skill, creativeness, and experiment skill. To explain the figure of intervention; the manifestations of AAK&S of students, STEM knowledge in the intervention,

2.3.1 Manifestations of AAK&S of students in STEM activities

Manifestations of AAK&S of students who are participating in STEM activities of manufacturing mixture of phosphate and potash fertilizer straws and waste of animal bones could be clarified as follows:

- Applying chemical knowledge to explain, prove the practical problems.
- Understanding and explaining chemical applications with different practical problems and areas.
- Understanding and explaining practical issues related to chemistry.
- Applying chemical knowledge and interdisciplinary knowledge (kiện thức liên môn) to explain some natural phenomena, applications of chemistry in life.
- Ability to analyze and summarize chemical knowledge in order to review and evaluate the impact of a practical problem.
- Evaluation: Applying the knowledge to debate, inspect the impact of a practical problem.
- Creation: Applying knowledge to propose some new methods, model designing, problem solving plan.
- Appropriate behavior in situations related to the health of themselves, their families and society. Appropriate behavior follows the natural requirements of sustainable development of society and environmental protection.

2.3.2 STEM knowledge in the intervention

- Science (S): Fertilizer knowledge about nutritious elements, roles, ingredients, methods in order to suggest ideas about resources and production process from straws and animal bones. Designing experiments in order to inspect the quality of fertilizer for plants.
- Technology (T): Using straws and animal bones could reduce environmental pollution as well as make use of raw materials to produce fertilizer. Fertilizer sample not only contains high levels of phosphorus, potassium, calcium but also improve the soil.
- Engineering (E): Fertilizer production process, machines which measure content of nutritious elements in fertilizer sample.
- Math (M): Method to build a baseline measuring P (phosphorus), K (potassium- kalium) and Ca (calcium) in fertilizer sample.

2.3.3 Process

STEM education intervention of manufacturing mixture of phosphate and potash fertilizer straws and waste of animal bones was developed regarding on the process in the figure 1.
Figure 1: process of developing STEM education learning activities [6]

**Step 1:** Identifying scientific issues. Creating ideas, teacher prepares activity-oriented questions as following:
- Searching science information through documents such as Chemistry textbook, Technical Chemistry textbook, and Analytical Chemistry. Teachers provided these questions:
  - What are the chemical elements of phosphate and potash fertilizer?
  - What is the role of phosphate and potash fertilizer for plants?
  - In industry, what are raw materials using to produce phosphate and potash fertilizer, and how to produce this kind of fertilizer?
  - If these raw materials are increasingly exhausted, what alternative sources of raw materials can be used?

- Organization for student to do research, analyze about economic and social situation in Ha Nam and identify the scientific issues. Teachers provided these questions:
  - Ha Nam is an agricultural province; the area of rice cultivation is large so there is the amount of straws after harvesting. To prepare for the next crop, farmers usually burn straws on the fields and it creates smoke that causes the environmental pollution. How to reduce this problem?
  - A number of animal bones from restaurants are dropped out the environment as solid wastes making the environment polluted. However, if the waste is treated thoroughly, it could bring high economic benefits, not only reduce environmental pollution. In animal bones contain mainly compounds of P are calcium phosphate Ca3(PO4)2 and hydroxyl calcium apatiteCa5(OH)(PO4)3 which could be made use of nutritious elements providing for plants (Dumitrescu, Manciulea, Sauciuc, Zaha 2009).
Step 2: Suggesting fertilizer production process. There are three phases including processed materials, phosphate fertilizer production, and phosphate and potash fertilizer production as following details.

Phase 1: Processed materials: Breaking and crushing bones into powder, laying straws in ashes. Students were provided two options including option 1: Using electricity to burn bones and crush into powder, burning straw on the fields to collect ashes; and option 2: Using straws to burn the bones in the incinerator, then collecting the ashes, and crushing the bones into powder.

Phase 2: Phosphate fertilizer production. There are two stages. The stage 1 is bone meal hydrolysis which provided two options including (1) option 3: using H$_2$SO$_4$ solution and (2) option 4: using H$_3$PO$_4$ solution. The stage 2 is neutralizing residual acid, rotting after neutralization to phosphate fertilizer.

Phase 3: Phosphate and potash fertilizer production which provided 2 options. These included (1) option 5: mixing ashes and phosphate fertilizer at a random proportion, and (2) option 6: mixing ashes and phosphate fertilizer at a specified proportion.

Step 3: Discussing (Manufacturing process). The direction of the activities in the step 2 should be discussing in the following aspects.

In phase 1 processed material: every group follows option 1 and 2 respectively. In option of using electricity to burn bones and burning straw on the fields, students use an oven to break bones around 24 hours, and it does not take advantage of the heat generated by the straws burning process. In option of using straws to burn the bones in the incinerator, students do experiments using straws to break bones in 1 hour so that it saves time, electricity and production costs. And, straw ashes for planting also helps making soil easier, providing some minerals such as Ca, Silica, Potassium, Phosphorus and some other trace elements. Besides, these ashes contain alkali so it could neutralize acidity in soil. Based on students doing two options, they may draw conclusion to choose the option of using straws to burn the bones in the incinerator.

Phase 2: Phosphate fertilizer production: Every group follows option 3 and 4 respectively.

- Option 3: Using H$_2$SO$_4$ solution
  + Stage 1: Hydrolyzing by H$_2$SO$_4$ solution with concentration about 57% (some documents applying concentration from 62% to 68%).
  + Stage 2: Neutralizing residual acid in fertilizer (If having) by NH$_3$solution or Ca(OH)$_2$ solution or bone meal.

- Option 4: Using H$_3$PO$_4$ solution
+ Stage 1: Hydrolyzing by H3PO4 solution diluted to concentration with the appropriate value.
+ Stage 2: Neutralizing residual acid in fertilizer (If having) by NH3 solution or Ca(OH)2 solution or bone meal.

Discussion in phase 2, students should discuss between 2 options above, if Option 3 is chosen, H2SO4 solution with concentration about 57% is a strong acid with high concentration, residual acid could create high acid environment that makes plants die. If Option 4 is chosen, H3PO4 solution is an average acid with low concentration, it does not contain residual acid but it provides phosphorus for fertilizer. Then, they may draw conclusion to choose the option 4.

Phase 3: Phosphate and potash fertilizer production: Every group follows option 5 and 6 respectively. Different crops have different demand for nutrient elements. Therefore, each crop has a different rate of mixing of phosphate fertilizer made from bones and potash fertilizer extracted from straw ashes as provided in the table 1 and 2. Based on these experiments, they may draw conclusion to choose the option 5.

Table 1: Dividing the proportion of phosphate to potash fertilizer outside the market which should be applied to some agricultural plants.

| Crops     | Productivity (Quintal/Ha) | The amount of nutrients used to produce 1 quintal of harvested product (kg/Quintal) |
|-----------|---------------------------|----------------------------------------------------------------------------------|
|           |                           | P2O5                              | K2O   |
| Rice      | 30                        | 0.4                               | 2.7   |
| Corn      | 20                        | 0.6                               | 3.0   |
| Sweet potato | 200                      | 0.1                               | 0.7   |
| Cassava   | 100                       | 0.1                               | 0.6   |
| Peanut    | 20                        | 0.7                               | 2.5   |
| Soybean   | 10                        | 0.7                               | 2.2   |

Table 2: Dividing the proportion of phosphate fertilizer to straw ashes (%P2O5 = 33.62%, %K2O = 36.8%) which should be applied to some agricultural plants.

| Crops     | Productivity (Quintal/Ha) | The amount of nutrients used to produce 1 quintal of harvested product (kg/Quintal) |
|-----------|---------------------------|----------------------------------------------------------------------------------|
|           |                           | P2O5                              | K2O   |
| Rice      | 30                        | 0.33                              | 1.57  |
| Corn      | 20                        | 0.3                               | 1.06  |
| Sweet potato | 200                      | 0.28                              | 1.5   |
| Cassava   | 100                       | 0.42                              | 1.75  |
| Peanut    | 20                        | 0.32                              | 0.8   |
| Soybean   | 10                        | 0.4                               | 0.78  |
Step 4: Implementing the process. These included preparing and implementing.

Preparing:
- Ingredients: Wastes of animal bones: 10 kg; Straws: 40 kg
- Chemical substance: H₃PO₄solution (concentration 80%); NH₃solution, Ca(OH)₂ solution
- Tools: Glasses with different capacity 50ml, 100ml, 200ml; grinder, hopper; measuring tube, glass chopstick; scale; oven, glass funnel, triangular vase, blue filter paper; beam bottle.

Implementing: Teachers divide the group and ask the students to follow the designed process as the figure 4 and experiment as the figure 5.

Figure 4: the designed process of implementing

Figure 5: The diagram of P.K. compound fertilizer modulation
Step 5: Evaluating the quality and calculating the price of the final product. Students had to calculate average price of manufacturing cost for making 1 kg. For example, they may calculate as following:

- Making the bone wastes into bone meal: 0.043USD
- Dust disposal (activated charcoal, calcium hydroxide solution): 0.043USD.
- $\text{H}_3\text{PO}_4$ (80%) solution (industrial type): 0.54 USD.

From 1kg of bone with chemicals and costs above, the researchers were able to modulate 1.8kg of M2 fertilizer. Hence, approximately 1kg of M2 fertilizer ($\%\text{P}_2\text{O}_5 = 33.62\%$, $\%\text{K}_2\text{O} = 36.8\%$) will be modulated at the cost of 0.35 USD (this is the modulation cost in the laboratory) while having the nutritious proportion twice as high than Lam Thao phosphate fertilizer and nearly up to par with potash fertilizer manufactured at Supe phosphate Lam Thao factory.

Comparing with Lam Thao phosphate fertilizer ($\%\text{P}_2\text{O}_5 = 16÷16.5\%$) costing 0.17 USD and($\%\text{K}_2\text{O} = 50\%-60\%$) at 0.43 USD, modulated fertilizer can offer much cheaper price, at 3.5 times lower than the market prices of other types of fertilizers (Lam Thao phosphate, potash) (binhdien.com 2018).

Besides, it is possible to reduce the price significantly by having it manufactured as mass-production. However, as samples of modulated compound fertilizer usually contain high nutrition ($\%\text{P}_2\text{O}_5$ from 27.82% ÷ 33.62%, $\%\text{K}_2\text{O} = 36.8\%$)), it could be used to produce high-quality fertilizer for special decorative plants/flowers. Also, compound fertilizer made from straws, rice husk, and animal bone wastes has significance to the environment as it could reduce the pollution partially.

Step 6: Testing on crops. Student started to experiment on two types of crops: Scallion and Kohlrabi with 5 different fertilizers, which are:

Sample 1: With Compound fertilizer modulated from straws, rice husk and animal bones (buffalo/etc.)
Sample 2: With Phosphate fertilizer made from animal bones.
Sample 3: With Potash fertilizer.
Sample 4: With Lam Thao phosphate fertilizer.
Sample 5: No fertilizer.

Results on scallion sample
After one month of experiments (From 21/5/2018 to 21/6/2018) in Crops at Nhân Chính commune - Lý Nhân District - Hà Nam Province, students measured the height and number of shoots in each scallion sample and got the final results as follow:

Final results from scallion (Density: 100 scallions/m$^2$), it showed that the sorting of quickest developed sample to slowest is sample 1, 2, 3, 4, and 5; respectively as showed height of scallion shoots in the table 2. And, pictures of samples testing were provided in the figure 6.

![Figure 6: Scallion samples for testing](image-url)
Table 3: Average height of scallion samples

| Date | 21/5 | 25/5 | 29/5 | 3/6 | 7/6 | 11/6 | 15/6 | 19/6 | 21/6 |
|------|------|------|------|-----|-----|------|------|------|------|
| Sample 1 | 9.1  | 10.2 | 11.5 | 12.5| 13.5| 15.3 | 17.2 | 19.75| 22.2 |
| Sample 2 | 7.5  | 8.3  | 9.4  | 10.3| 11.2| 13.2 | 15.4 | 17.5 | 19.4 |
| Sample 3 | 6.6  | 7.2  | 8.1  | 8.5 | 9.5 | 10.5 | 11.5 | 12.75| 14.6 |
| Sample 4 | 5.8  | 6.5  | 7.4  | 8.2 | 9.2 | 10.2 | 12.5 | 14.25| 15.8 |
| Sample 5 | 2.4  | 3.2  | 4.5  | 5.8 | 6.7 | 7.3 | 8.5  | 10.3 | 12.5 |

Hence, the modulated compound fertilizer has positive effect on scallion testing samples as it made the green shoots developed quicker and higher than other samples (which were manured with other types of fertilizer, such as Lam Thao phosphate fertilizer or no fertilizer at all).

To increase the practical value, the researcher conducted the experiment on several crops of local farmers:

+ Size: Height 5m; Width 1.2m
  + Density: 100 scallions/m²
+ Time: From 21/5/2018 to 21/6/2018
+ Place: Crops at Nhân Chính commune - Lý Nhân District - Hà Nam Province

Table 4: Effect of the modulated compound fertilizer on scallion testing samples

| Result                          | S1     | S2     | S3     | S4     | S5     |
|--------------------------------|--------|--------|--------|--------|--------|
| Average height (cm)/scallion    | 14.6   | 12.5   | 9.9    | 10.0   | 6.8    |
| Weight (kg)/6m²                 | 2.5×6=15 | 2.30×6=13.8 | 2.15×6=12.9 | 2.1×6=12.6 | 1.7×6=10.2 |
| Profit/1 scallion furrow (USD)  | 13     | 12     | 11.2   | 11     | 8.9    |

Figure 7. The graph show the testing results of scallion
Final results on kohlrabi sample

Table 5: Average size of kohlrabi bulbs with 5 different samples

| (Date)  | 21/5 | 25/5 | 29/5 | 31/5 | 3/6 | 5/6 | 7/6 | 9/6 |
|---------|------|------|------|------|-----|-----|-----|-----|
| Sample 1| 3.55 | 4.88 | 6.975| 9.52 | 13.035| 14.02| 15.04| 17.88| 19.045|
| Sample 2| 3.2  | 4.28 | 6.34 | 9.345| 11.53 | 12.68| 13.99| 16.33| 18.535|
| Sample 3| 2.95 | 4.235| 6.185| 8.155| 9.99  | 10.735| 12.785| 15.845| 18.465|
| Sample 4| 2.65 | 4.035| 5.835| 8.035| 9.485 | 10.48| 12.485| 14.99| 17.11 |
| Sample 5| 1.85 | 2.985| 3.81 | 5.13 | 6.375 | 7.97 | 9.285 | 10.28 | 11.54 |

From the result above, shows that:
- Sample 1 developed quickest
- Sample 2 developed slower
- Sample 3 developed slower than sample 2
- Sample 4 developed the same with sample 3
- Sample 5 developed slowest

Hence, the modulated compound fertilizer has positive effect on kohlrabi testing samples as it made the bulbs developed quicker and bigger than other samples (which were manured with other types of fertilizer, such as Lam Thao phosphate fertilizer or no fertilizer at all).

To increase the practical value, the researcher conducted the experiment on several crops of local farmers:
- Size: Height 5m; Width 1,2m
- Density: 25 kohlrabi bulbs/m²
- Time: From 21/5/2018 to 21/6/2018
- Place: Crops at Nhân Chính commune - Lý Nhân District - Hà Nam Province

Table 6: effect of the modulated compound fertilizer on kohlrabi testing samples

| SAMPLE | S1 | S2 | S3 | S4 | S5 |
|--------|----|----|----|----|----|
| Diameter/ 1 bulb (cm) | 10.5 | 10.1 | 9.2 | 9.1 | 7.3 |
| Average weight (kg)/6m² | 0.35×150= 52.5 | 0.3×150 = 45 | 0.26×150= 39 | 0.25×150 = 37.5 | 0.15×150 = 22.5 |
Step 7: Reporting the final results

1. Students started to test and found the optimal conditions for the procedure of modulating compound fertilizer from animal bones, which are:
   - Mixing proportion: Weight of bone meal/ volume of H$_3$PO$_4$ solution = 50g/150ml.
   - Acid H$_3$PO$_4$ solution proportion: H$_2$O (v:v) appropriate proportions are (75:75); (60:90); (50:100) and (37,5:112,5). Especially, (60:90) is most suitable.
   - Time for liquid acidic composting is 14 days.

2. Result for finding P content in phosphate fertilizer

The results of finding total content of % P$_2$O$_5$ in animal bone meal in 5 different fertilizers are presented in the Table 7 below.

| Sample | Animal bone wastes | Straws burning time (minutes) | Composting time (days) | P content in sample (µg/g) | P (%) | P$_2$O$_5$ (%) |
|--------|-------------------|-------------------------------|------------------------|---------------------------|-------|---------------|
| S1     | Pig               | 40                            | 14                     | 266194,60                 | 13,31 | 30,56         |
| S2     | Mixed             | 45                            | 14                     | 231759,17                 | 11,69 | 26,59         |
| S3     | Mixed             | 30                            | 14                     | 241228,65                 | 12,06 | 27,63         |
| S4     | Buffalo/Cow       | 60                            | 14                     | 231532,46                 | 11,58 | 26,57         |
| S5     | Buffalo/Cow       | 50                            | 14                     | 224335,32                 | 11,22 | 25,8          |

Figure 9. The graph show the testing results of kohlrabi
Figure 10. The graph shows P₂O₅ content in fertilizer samples

- From the result of finding total content of % P₂O₅ in 05 different fertilizers, shows that
  + Ability of P in animal bones changing from indissoluble to dissoluble is relatively good.
  + % P₂O₅ in buffalo/cow is higher than in pig bones. Also, the required straw burning time for
    buffalo/cow and pig are 60 minutes and 40 minutes, respectively. Thus, it is less time-consuming to
    burn pig bones than buffalo/cow bones.

3. After actual test on 2 samples, which are Scallion and Kohlrabi, the results showed that
   modulated compound fertilizer had high economy efficiency and affected positively towards crops:
   - The kohlrabi sample manured by compound fertilizer brought better results with bigger bulbs
     and quicker development, than other samples with different fertilizers: phosphate fertilizer from
     buffalo/cow bones, Lam Thao fertilizer, potash fertilizer, and no fertilizer.
   - The scallion sample manured by compound fertilizer brought better results as it grew taller
     with more green shoots and quick development.

3. Findings
The process of the pedagogical experiment, provided in the section of 2.3.3, was implemented to
students at Grade 11 chosen randomly, in some class 11A4 – Lý Nhan high school, Lý Nhan district,
Ha Nam province. The findings clarified the results of implementing in Lý Nhan high school. The
findings revealed the following aspects:

3.1 Students and teachers’ evaluating on the designed STEM activities provided chance for
AAK&S

3.2 Comparing the AAK&S between male and female students

3.3 The development of students’ AAK&S during their STEM activities

3.1 Students and teachers’ evaluating on the designed STEM activities provided chance for AAK&S

For teachers, in order to evaluate whether STEM activities can be applied as above and create
opportunities for students to practice their AAK&S, the researchers has gathered teachers’ opinions
from 25 different teacher from: Lý Nhàn high school; Bắc Lý high school; Nam Lý high school; Nam
Cao high school; Lý Nhàn commune - Hà Nam province. The result (figure 11) shows that nearly all
teachers agreed that the STEM theme in the unit of “Manufacturing P.K. modulated compound
fertilizer from straws and animal bone wastes” provided students chances to practice AAK&S.
For students: based on the above process of AAK&S, the researchers listed out how much AAK&S students showed during their scientific research period. From data in observation assessment of teachers, the researchers collected initial results. It indicated that the STEM activity could provide good chance for students to practice their AAK&S. Especially, step of actual situations (Step 1) and step of discussing fertilizer manufacturing process (Step 3) could provide the most chances of students showing their AAK&S. This could be seen as the Figure 12.

Figure 11. Results showing chances of students in practicing AAK&S

Figure 12: Chances of showing AAK&S in each stage in the organizing process of the STEM activity (approx. 20 students)
3.2 Comparing the AAK&S between male and female students

The researchers were also curious about if there is a difference between genders in terms of developing AAK&S. Here is the final outcome based on 2 different groups: a group of 10 male students and the other of 10 female students. Male students complete the required activities before the female group 10 days as information in the Table 8. This shows that male students do have better AAK&S than female students in STEM activities. The results also allow the research to come to the conclusion that female students tend to be shy and reluctant to communicate, thus affect their own AAK&S in STEM activity. Moreover, STEM activities might not be a strong points of female students. Hence, it is recommended to divide equally the number of male and female students in a group while doing other STEM activities. On one hand, this could let students having higher AAK&S to help other members in the group. On the other hand, male students could handle heavy, physical work, while female students are able to focus on details when they are working on a STEM activity together.

Table 8. Targets and required time to finish the activity

| Target          | Number | Required time to finish the activity               |
|-----------------|--------|---------------------------------------------------|
| Male student    | 10     | 21/09/2018- 21/10/2018                            |
| Female student  | 10     | 21/09/2018- 31/10/2018                            |

3.3 The development of students’ AAK&S during their STEM activities

After completing the STEM activities systematically, in order to evaluate the development of students’ AAK&S during their STEM activities, the researchers propose an observation point assessment. This allows teacher or student to check and give points based on 5 criteria mentioned earlier. Table 9 is the Observation points and will be given to each student by teachers. There in each criterion will be rated with scores range from 1 to 4. 1 means one point, 2 means two points, 3 means 3 points, and 4 means 4 points. The result is described as follow:

Table 9: The result of evaluating AAK&S based on the Observation point assessment

| Criteria No. | Experiment group | Control group | Experiment group | Control group |
|--------------|------------------|---------------|------------------|---------------|
|              | The number of students score | Criteria average point | The number of students score | Criteria average point |
| 1            | 1,0 2,0 3,0 4,0 | 3.25 | 1,0 2,0 3,0 4,0 | 3.25 |
| 2            | 1,0 2,0 3,0 4,0 | 3.20 | 1,0 2,0 3,0 4,0 | 3.20 |
| 3            | 1,0 2,0 3,0 4,0 | 3.30 | 1,0 2,0 3,0 4,0 | 3.30 |
| 4            | 1,0 2,0 3,0 4,0 | 3.20 | 1,0 2,0 3,0 4,0 | 3.20 |
| 5            | 1,0 2,0 3,0 4,0 | 3.15 | 1,0 2,0 3,0 4,0 | 3.15 |
| Problem-solving capacity average point of experiment group = 3.22 | Problem-solving capacity average point of control group = 2.52 |
| The difference of average point = 0.74 | |
| The S.D. of experiment group = 0.94 | The S.D. of control group = 1.10 |
| Allow independent verification test p= 1.28.10^-06 | |
| ES level = 0.64 | |
According to the table 9, the number of criteria could be labelled as following. Criteria number 1 is Systematize and categorize chemistry knowledge. Criteria number 2 is Collect and classify knowledge. Criteria number 3 is Recognize chemistry knowledge based on actual application. Criteria number 4 is Recognize problem during actual application and use learned knowledge to solve. And, criteria number 5 is Independent and creative when handling actual problems. The development of students for each criteria could be represented as mean score in the figure 13.

Figure 13. The graphs describe the ability to apply knowledge of students

According to the Figure 13, each criterion of AAK&S that the researchers evaluated during the experimental process of the chosen class, has all increased (as described in the left figure, each line of ability increases; in the right figure, the experiment group’s line is higher than the control group).

According to the Table 9, the results in the table prove that the chosen experimental class for STEM model had much higher observation points than a class receiving traditional teaching (The different between Experiment group and Control group is 0.74). That proves STEM in education affect students greatly in the ability of apply knowledge and skills in studying chemistry.

Effect size (ES): ES = 0.64. This ES value shows that using STEM model has affected students greatly in the development of their AAK&S. The p value for experiment group and control group is always < 0.05, hence proved there is no randomness in the STEM experiment “Manufacturing compound fertilizer from straws, rice husk and animal bones”. STEM applied in this activity has brought a great result.

During the process of designing STEM activities, the researcher decided that the first step (1st activity) and the last step (7th activity) would share the same level of difficulty. This was to let each student to show their ability equally. The final data analysis shows, through STEM activities, most students’ scores went up (comparison between the 1st activity and the 7th activity), however, the results did vary among students. Some students had significant increase in their scores, while some others remained stable. The results also had no record of students whose AAK&S score decreased. Again, this reaffirms that STEM activity can increase students’ AAK&S
4. Conclusion
With the objectives of building and developing students’ ability, the discovering and using STEM advantages are totally beneficial and necessary towards Vietnamese education. Applying STEM in teaching science brings great effect in students’ study. Student learns about how to collect needed information, show their creativeness, develop and improve their team-work skills or presentation skills. Also, increase their awareness in protecting the environment as well as their passion in pursuing science careers in the future.

From the actual experiment results, the researchers can conclude that it is possible to help student develop their AAK&S through STEM activities. Teaching and following STEM orientation will require teachers to select and design STEM activity, while ensure the practical value and familiarity with students. The teacher could use STEM activity as the motivation for students in studying science and create a safe, friendly environment, encourage them to ask questions or brainstorm new ideas.

The results concluded in this research recommend a new experiment on a broader and longer research to deliver more highly reliable results in the future, and will be applicable widely for other target groups, such as students in secondary schools or in universities.

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