Hacking STEM - a solution to teaching natural science subjects in secondary schools for STEM-oriented education

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Abstract. In the new general school curriculum, the Natural Science subject is taught in an integrated way according to the STEM-oriented education. However, it is not simple to build a topic of teaching Natural Science subject towards STEM standards. In this context, Hacking STEM is one of the ideal solutions to solve the aforementioned problem. The paper focuses on analyzing what Hacking STEM is, the advantages and disadvantages of Microsoft Hacking STEM when applied in Vietnam, the process of using Microsoft Hacking STEM projects, analyzing a specific project, the relationship between these projects with the Natural Science subject in the new general school curriculum and with the subjects of Natural Sciences being taught in the current period.

Key words. Hacking STEM, STEM, the Natural Science subject, general school curriculum

1. Introduction

STEM education is considered to be the right step in the current stage when it is suitable for Vietnam's educational objectives of developing learners' competences and qualities. In the new general school curriculum, the Natural Science subject will be taught in an integrated way under the STEM-oriented education, but to prepare for this, we have to put STEM into teaching right at the current stage [1], [2]. However, it is not easy to build a teaching topic for the Natural Science subject under the STEM standards and integrate STEM into the current curriculum when many teachers who play a key role in the educational innovation are quite vague about how to teach the Natural Science subject and still do not understand what STEM is, how to organize a STEM topic lesson [4], [5], [6], [7]. In this context, Hacking STEM is one of the ideal solutions to solve the problem when utilizing the knowledge resources of teachers around the world. Therefore, we focus on analyzing what Hacking STEM is, advantages and disadvantages of Microsoft Hacking STEM when applied in Vietnam, steps to use Microsoft Hacking STEM projects, analysis of a specific project, the relationship between these projects with the Natural Science subject in the new general school curriculum and with the natural science subjects that are being taught in the current period.

2. Situation and problems

2.1. What is Hacking STEM?

When you are stuck with ideas but still want to participate in quality community projects, Hacking STEM is an ideal solution. So what is Hacking STEM? It can be understood that it is the way to exploit the existing STEM projects to follow and develop them basing on one’s own conditions.

There are many websites about STEM, but Microsoft's Hacking STEM site is more complete. Microsoft Hacking STEM enables you to conduct get-to-know activities and rely on visual data access through the entire programs of science, technology, engineering and math. Hacking STEM projects is an approach to knowledge through the activities of exploration and problem-solving and provide a wealth of experience in both physics, digital technology and topic exploration [3]. Therefore, applying STEM will be effective not only in terms of knowledge but also training skills for students. Currently on the Microsoft Hacking STEM Library there are over 30 projects with different levels such as Party
lights, Brain impact simulator, Comparing speeds, Exploring our oceans, Distance wheel and angle finder, EC sensor, Light gate, Seismograph, Telegraph, Tuned mass damper, Sensorized glove and robotic hand, Anemometer, Windmill and wind turbine…

Figure 1: Projects in the Microsoft Hacking STEM library
(Source: https://www.microsoft.com/en-us/education/education-workshop/activity-library.aspx)

2.2 Advantages and disadvantages of Microsoft Hacking STEM Library

2.2.1 Advantages. On this page, there is a full range of materials from materials for teachers to materials for students, from text to picture. The images are illustrated in a visual, detailed way to make it easy to follow even though the instructions are in English.

All materials are saved online on OneNote to facilitate searching.

Figure 2: Using the OneNote to save a document
(Source:https://www.microsoft.com/en-us/education/education-workshop/activity-library.aspx)

All documents are standardized with full, detailed instructions, from the knowledge standards to the project evaluation criteria to test learners’ ability according to NGSS of the United States (Next Generation Science Standards).
### Figure 3: Project standards of the United States

(Source: https://www.microsoft.com/en-us/education/education-workshop/activity-library.aspx)

At these sites, you are encouraged to "hack" their projects. It can be said that they are the original projects, but anyone can make reference to following without fear of losing their own creative independence. Because we can completely change the subject and scope of research. In addition, projects have lesson extensions, whereby project hackers can create many related projects.

In the process of implementation, you can completely exchange information with the original project team, or with groups doing projects the same as yours through STEM groups, post the project results to the original website to share information.

#### 2.2.2 Disadvantages and solutions

All materials are posted in English, so teachers are required to carry out translation while there are many words related to different subjects. This requires teachers to improve their foreign languages or use online translation tools to understand the spirit of the project.

When selecting students to join the project, teachers can prioritize students with good English proficiency, or ask English teachers to check the translation of materials or collaborate with them on a project.

Microsoft Hacking STEM Library is a good data warehouse, but it is difficult to deploy in practice due to certain requirements of materials and technology. There may be some specialized equipment which are expensive or difficult to buy in Vietnam so teachers must improve their methods to suit the conditions of Vietnam.

For example, in the project EC sensor "Measuring Water Quality to Understand Human Impact", there are some materials that can be replaced without losing the accuracy of the knowledge content.

- The project requires the preparation of deionized water to be distilled water but in reality, it is not simple to get standardized distilled water because it is quite expensive and used much when implementing. Therefore, project developers must look for acceptable deionized water types in the market, which may be Aquafina or AAA with a concentration of about 1-2 ppm.
- In the project, there are instructions for making Sensor, but the steps are quite complicated, so when making Sensor yourself, the teacher should give students suggestions of how to make it as simple as possible while ensuring accurate adjustment of EC sensor digital.
Or Ms. Vu Dung, Bac Giang Province, instructing students to build the robot arm of the Robot-Sensorized Glove and Robotic Hand project, substituted Velostat film priced a few tens of usd /strip of a few cm² with paper and pencil film to create pressure-sensitive conductive materials to suit the design of extremely cheap conductive sensors, which are suitable for every school in Vietnam. She and the students won a prize in the Youth and Children’s Creative Contest. Ms. Hoa Van, Hanoi, instructed students to study alternative materials for Velostat film and won the Second Prize of the Hanoi Science Research Competition for Students 2018.

Most projects have certain requirements for the information technology, so teachers have to update some additional technologies such as programming for Arduino Uno processor chips, Excel, processing analog data. While carrying out the projects, we realized the ability of Excel’s incredible data collection and processing when combined with the Córdoba Add-in and that of Power BI’s when combined with Arduino.

3. Results and discussion

3.1. Steps to implement Hacking STEM project

Step 1: Material study
• Go to Hacking STEM site to get to know the projects.
• Read briefly about the projects presented in the library to find the project that best suits you.
• Download the project’s learning materials and translate them into Vietnamese. Study the entire project from materials for teachers and students, from the evaluation criteria to the steps of the project implementation.
In this step, the teacher can divide students into groups to translate the materials, both for students to understand the steps of the project and to improve their English reading comprehension skills. The teacher then adjusts those materials to the best.

Step 2: Facility preparation
In this step, the teacher and students prepare enough tools, chemicals and samples. Teachers should encourage students to prepare equipment and materials that they can collect on their own. This helps students understand the lesson content and helps them develop a sense of responsibility with the project results. For example, in the project "Measuring Water Quality to Understand Human Impact", students could prepare their own straws, steel wires, copper wires, iron clamps, soda cans, scissors, tape, etc. In the project "Brain impact simulator", students can prepare balloons, parachutes, cue balls, paperboard, etc.

For some projects, teachers need to find out which materials are difficult to prepare in Vietnam or are expensive so that they can have alternative plans. In the project "Measuring Water Quality to Understand Human Impact", we replaced distilled water with Aquafina water, replaced backing soda with salt and still got the same results.

Or in some projects such as the "Measuring Water Quality to Understand Human Impact" that need to collect samples, teachers need to train students to practice water sampling skills to ensure the objectivity such as taking as many water samples as possible, the distance to get water samples from the same place, time to get the samples, how to record, etc.

Step 3: The project implementation
This step is divided into 2 phases.
• Phase 1: Studying background knowledge
During this phase, the teacher allows students to conduct research experiments for the project, which explains some of the phenomena that will be encountered during the students’ project work.
• Phase 2: In-depth research
During this phase students conduct intensive research according to the instructions.

The project "Measuring Water Quality to Understand Human Impact" includes the following contents: Activity overview, Analog EC sensor, Digital EC sensor, connect Arduino Uno, connect micro:bit, data Streamer set-up, data streamer basics, preparing water samples and calibrating EC sensor, excel work basics.

Step 4: Discussion and learning from experience of product improvement
After the research results, students discuss with each other, analyze the results to draw conclusions.

In the project "Measuring Water Quality to Understand Human Impact", we conducted a successful adjustment of digital sensor equipment and used it to measure water samples collected in three areas, namely Dao River, Vi Xuyen Lake, Loc Ha ditch in Nam Dinh city. The result of the measurement difference between the self-manufactured equipment and a commercial TDS tester is between 10 ppm and 50 ppm (this is an acceptable difference).

In addition, the results show that the water sample in Loc Ha ditch gave a higher concentration than the two water samples in Dao River and Vi Xuyen Lake, the amount of dissolved solids is much, the smell is unpleasant, the color is light yellow, dark yellow and black. Two water samples from the Dao River and Vi Xuyen Lakes gave the TDS solubility concentration within the acceptable range, the results on Zone Ecosystem showed that fish still survived. But the water sample of Loc Ha ditch has a very high TDS, showing the dangerous results, many fish bones found, all of which prove this is a
poisonous, unsafe environment. This is entirely consistent with the fact that Loc Ha ditch is a place to discharge domestic water of Nam Dinh city with black water and very unpleasant stench all year round.

However, there are many factors to assess water quality, teachers need to teach students that the TDS is only one of the indicators for water quality.

In the implementation, we found some experiences as follows:

- When the value of the voltage is increased but the concentration does not go up and vice versa, apart from the reason of wrong plugging, there is a simple reason that the wrong dot and comma are entered in the decimal symbol. Simply because the workbook is designed by a foreign teacher, the decimal notation is different. The solution is to go to control panel \ clock and Region \ change date, time or number formats. In the format tab select English (United States) \ Apply \ OK.

- When Voltage value in Excel workbook does not appear, please check the circuit connection and previous installation steps. When measuring the value of Voltage, EC sensor should be stable for 1-2 minutes before reading the value for accurate results.

  - EC sensor can be made of steel wire, or copper wire. For the accurate results, use a new type of wire with no rust.

  - Chemicals should be weighed in cup (not using paper) to ensure that all the salt can be dissolved in water and not adulterated from paper (including filter paper); paraffin-coated paper can be used, too.

To increase the interoperability, Microsoft's Hacking STEM Library allows you to submit project results to the original website for information sharing. This helps connect projects from many parts of the world, helping students integrate into human knowledge.

Step 5: The project expansion

This is, in fact, phase 3 of step 3. Based on the results teachers guide students to expand the project in different directions according to their own conditions. For example, in the project "Measuring Water Quality to Understand Human Impact", it can be expanded to research the water quality of more regions, or to study the effect of using chemical fertilizers on water quality, or measuring concentrations ppm to make a solution for growing plants in hydroponic vegetable project.

3.2. The relation between the projects in the Microsoft Hacking STEM Library and the Natural Science subject of the new general school curriculum and that of the current curriculum

When analyzing the data warehouse in the Microsoft Hacking STEM Library and through the project process, we found that the knowledge in these projects is closely related to the Natural Science subject of the new general school curriculum and that of the current curriculum.

For example, the project "Measuring Water Quality to Understand Human Impact" uses the knowledge content of the following subjects:

- Chemistry: the knowledge of solutes, solvents, solutions, solution concentration, how to prepare solution concentrations of Chemistry 8 according to the current curriculum and the content of chemical metabolism of Chemistry 8 according to the new general school curriculum; the knowledge of electrolytes, the ion dissociation of substances in water of Chemistry 11. In addition, there are also extension lessons such as the concentration of PPM.

- Physics: board assembly, EC sensor design, voltage, resistance of Electrical - Physics 8 according to the current curriculum and the content of Electrical - grades 8, 9 according to the new general school curriculum.

- Biology: Ecology of water environment according to the current curriculum and the content of Environment and ecological factors, Ecosystem, Natural balance, Environmental protection according to the new general school curriculum.

- Mathematics: use algorithms to calculate the solution concentration, calculate the slope of linear equation.

- Information Technology: Excel; in addition, the extensive knowledge of softwares such as Arduino, Córdoba ...

• Fine Arts: color scheme in poster design, logo for the project.
The project "Brain impact simulator" uses a lot of knowledge related to the nervous system of the section of human anatomy in Biology 8 according to the current curriculum and the content circuit of the nervous system and human senses - Grade 8 according to the new general school curriculum.

The "Telegraph" project uses the knowledge of Sound Study of Physics 7 according to the current curriculum and the content of Sound - grades 7 and 8 according to the new general school curriculum.

However, a limitation is that the knowledge content in the above projects is mostly for high school students, so if teachers want to apply them in the Natural Science subject in the new general school curriculum program or the subjects of natural sciences of the current curriculum, the teacher should refine the knowledge, limit the project, as well as select projects that are appropriate for secondary students.

4. Conclusions
As such, it can be seen that the Microsoft Hacking STEM site is very useful for referencing the projects for teachers who really want to teach standard STEM. Hacking existing projects helps teachers minimize time spent on groping while still participating in quality projects. In addition, we found that when students participated in the above projects, they developed a lot of competencies such as problem solving, creativity, information technology processing as well as English reading comprehension. The above projects can be fully expanded and developed into scientific research projects, thus, can train students to develop the thinking of scientific research. In the current period when the current curriculum is still quite heavy in theory and the new general school curriculum is about to be implemented in the STEM-oriented integration, the exploitation of the projects on the Microsoft Hacking STEM site is the necessity and accumulation of experience for teachers, the premise of initiating the new general school curriculum.

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