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STEM Education: Organizing high School Students in Vietnam using Engineering Design Process to Fabricate Water Purification Systems

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Abstract Engineering design process is one of the problem – solving approachs used in STEM education. Students can engage in the practices of the engineering field through solving problems using the engineering design process. Based on literature reviews on Engineering design process as well as fabricating water filter system, this study presents 36 tenth-grade students of high school in Vietnam completed an engineering-based problem on filtering water involving integrated STEM learning. Students employed five – step engineering design processes and STEM disciplinary knowledge to plan, sketch, construct, evaluate and redesign water filter systems taken from public fountains, tap water, river water, sea water, and water contaminated with alum.

Keywords: *STEM education, engineering design process, water filter systems, problem – solving approachs*

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1. Introduction

In harmony with the flow of the world, Vietnam's education is also transforming on competency-based approach to supplying human resources for the industrial revolution 4.0, especially human resources in STEM careers. Increasingly, science, technology, engineering, and mathematics (STEM) education is being recognized internationally as underpinning economic growth and advancing the skills that societies need for the 21st century [1,2,3]. As emphasized in the 2013 report from the U.S. Committee on STEM Education, "The jobs of the future are STEM jobs," with STEM competencies increasingly required not only within, but also outside of, specific STEM occupations (National Science and Technology Council, 2013).

A evident in Honey et al.'s report, "STEM Integration in K–12 Education: Status, Prospects, and an Agenda for Research". The report provides a basic definition of integration, namely, "working in the context of complex phenomena or situations on tasks that require students to use knowledge and skills from multiple disciplines" [4]. More specifically, the STEM Task Force Report (2014) views STEM education as not just a "convenient integration" of the four disciplines, but rather, as encompassing "real-world, problem-based learning" linking the disciplines "through cohesive and active teaching and learning approaches". Further emphasizing their focus on STEM integration, the report argues that the disciplines "cannot and should not be taught in isolation, just as they do not exist in isolation in the real world or the workforce" [5].

One approach to developing more integrated STEM learning is through engineering experiences housed in real-world contexts that utilize mathematics, science, and technology concepts. Such experiences remain neglected in the elementary and middle grades even though engineering provides a foundational, cross-disciplinary link [6,7]. For example, research has demonstrated how engineering-based experiences can develop young students' appreciation and understanding of the roles of engineering in shaping our world, and how it can contextualize mathematics and science principles to improve achievement, motivation, and problem solving [8]. Despite the recognized contributions of engineering education within STEM learning, the discipline remains largely underrepresented in the elementary and middle grades.

In this article we address tenth-grade students' approaches to solving an engineering-based problem on filtering water, which drew on the students' curriculum in mathematics, science, and design and technologies. The problems involved the design of three-dimensional (3D) models that were constructed, tested, redesigned, and further tested in generating final products that met given criteria and constraints. For the present problem, students applied their preliminary learning about filtering principles to the design and construction of water filtering systems taken from public fountains, tap water, river water, sea water, and water contaminated with alum. Students employed engineering design processes and STEM disciplinary knowledge in building their structures, taking in to account constraints of cost and materials, and subsequently tested their products. Using the test results, the students completed a second design to construct water filtering systems that would better.

One of the challenges in designing and implementing integrated STEM experiences is to ensure both content and processes are developed [9]. It is important that students are able to apply their understanding of core STEM concepts without these being over shadowed by the construction component itself. Research has shown that this has been an issue with some engineering-based activities when the motivation to produce an artifact takes precedence over the development of science concepts. Hence in designing the water filtering problem, we focused on students' development and application of core mathematics and science concepts, with engineering (and technology) design processes driving this conceptual growth during problem solution. As such, previous research on engineering design-based problem solving and the identified processes young students use when engaged in these activities provided a foundation for our research.

2. Content

2.1. Defining STEM Education

In the 1990's the National Science Foundation united science, technology, engineering, and mathematics and created the STEM acronym—a strategic decision made by scientists, technologists, engineers, and mathematicians to combine forces and create a stronger political voice. STEM education, however, is much more than a convenient integration of science, technology, engineering, and mathematics; it is an interdisciplinary and applied approach that is coupled with real-world, problem-based learning. STEM education integrates the four disciplines through cohesive and active teaching and learning approaches. We now understand that these subjects cannot and should not be taught in isolation, just as they do not exist in isolation in the real world or the workforce [5].

In which Engineering is both a body of knowledge about the design and creation of human-made products and a process for solving problems. This process is design under constraint. One constraint in engineering design is the laws of nature, or science. Other constraints include time, money, available materials, ergonomics, environmental regulations, manufacturability, and reparability. Engineering utilizes concepts from science and mathematics as well as technological tools [5]. Engineering is a natural integrator. Many STEM integration efforts revolve around using engineering and engineering design as the impetus for learning science, mathematics, and technology content. The National Research Council's Framework for K-12 Science Education (2012) articulates and discusses the role of engineering as a mechanism by which students can learn meaningful scientific concepts. This document moves the conversation from broad sweeping reforms and abstract ideas to the concrete by advocating for national science standards that include engineering [9].

In STEM education, engineering - the process of designing, building, and using engines, machines, and structures - is often ignored even though it is the key to authentic STEM instruction. For some teachers, engineering is intimidating as it's rarely mentioned in science, math, or technology teacher preparation. For others, it's daunting. It seems like a lot of planning to successfully implement an engineering design project, which is not essential to science, math, or technology instruction. The key to successful STEM teaching is the integration of science, math, and technology. In STEM careers, scientists don't only do science and applied mathematicians don't only do math, instead they work across disciplines. So, to mirror the work of STEM professionals and increase college and career readiness, it's important that students experience real-world, integrated projects in the classroom. Engineering bridges all of the STEM disciplines and provides students with authentic opportunities to think and act like engineers and scientists.

2.2. Engineering Design-based Problem Solving

Design is widely considered to be the central or distinguishing activity of engineering [10]. It has also long been said that engineering programs should graduate engineers who can design effective solutions to meet social needs. Despite these facts, the role of design in engineering education remains largely as stated by Evans et al. in 1990: "The subject [of design] seems to occupy the top drawer of a Pandora's box of controversial curriculum matters, a box often opened only as accreditation time approaches. Even 'design' faculty - those often segregated from 'analysis' faculty by the courses they teach - have trouble articulating this elusive creature called design" [11].

Engineering design technologies using an understanding of science and math. In this way engineering provides the glue to hold science and math together and provides meaningful situational context [12].

Recent studies have revealed how elementary school students are capable of solving problems involving goal-directed engineering design processes including planning, sketching, constructing, and evaluating. Various interpretations of engineering design have appeared in theliterature. Engineering experiences in the elementary and middle schools frequently adopt the broad, iterative processes of (a) defining problems by identifying criteria and constraints for acceptable solutions, (b)generating a number of possible solutions and assessing these to determine which best meet the problem requirements, and (c) optimizing the solution by systematically testing and refining, including overriding less significant features for the more important. The iterative feature of engineering design can be particularly powerful for school students, as it prompts them to test and revise a possible solution to create the best possible outcome, thus potentially promoting "learning while designing" [13]. The newly released Next Generation Science Standards highlight the importance of engineering in elementary school classrooms [14].

Design processes are at the center of engineering practice. Solving engineering problems is an iterative process involving preparing, planning, and evaluating the solution at each stage including the redesign and improvement of current designs. At the K-12 level, students should learn the core elements of engineering design processes and have the opportunity to apply those processes completely in realistic situations. Although design processes may be described in many forms, certain characteristics are fundamental [9].

When engineers solve a problem, their first solution is rarely their best. Instead, they try different ideas, learn from mistakes, and try again. The series of steps engineers use to arrive at a solution is called the design process. A formal definition of engineering design is found in the curriculum guidelines of the Accreditation Board for Engineering and Technology (ABET). The ABET definition states that engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and engineering sciences are applied to optimally convert resources to meet a stated objective. Among the fundamental elements of the design process is the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. The engineering design component of a curriculum must include most of the following features: development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statement and specifications, production processes, concurrent engineering design, and detailed system description. Furthermore, it is essential to include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact [15].

According to the National Research Council’s (NRC) framework, this engineering design process is key to helping students to learn about engineering, which then increases their interest in the field [16]. Many researchers propose engineering design process as a means of solving challenges in STEM fields. The Massachusetts Department of Education. Proposed eight steps of engineering design process which provide a guide for teachers and curriculum coordinators regarding learning, teaching, and assessment in science and technology/engineering specific content from Pre-Kindergarten to Grades 6-8 and throughout high school. Those eight steps of engineering design process include identifying the need or problem, research the need or problem, develop possible solution(s), select the best possible solution, construct a prototype, test and evaluate the solution, communicate the solution, and redesign. Wendell, Wright, and Paugh (2015) found evidence that specific instructional support built upon student resources could create more pathways to success and learning during the different phases of engineering design. Additionally, students could create and communicate design ideas to each other while engaging in practices. The use of the engineering design process as an instructional framework is intended to ensure that all pedagogical practices are contextualized within the engineering design process so that students research, calculate, test, brainstorm, build and perform activities to fulfil STEM-design challenges. Many researchers claim that STEM curricula can be integrated in an engineering design process to provide a mechanism through which students learn relevant STEM content. This mechanism encourages students to make connections, helps connect design failure or next steps to real world engineering and technology. Students learn important scientific concepts and their application in engineering and technology, as well as their relationship and application in daily life or real world context. Students could look for connections by engaging with activities or material in 'real-world' contexts to establish relevance. This approach can attract students‟ interest in science lessons and provide them with a deep understanding of concepts and meaningful learning. A research by Neo, Neo and Tan (2012) found that activities that students carry out in the real world were effective in teaching and engaging students in the classroom as well as increasing their understanding of the subject matter [17]. NGSS includes a three-step engineering design process (Define, Develop Solutions, Optimize) with indicators for different age groups (K-2, 3-5, 6-8, and 9-12). The emphasis on engineering in these new science standards highlights both the importance of engineering and the drive to ensure that even young students are exposed to the field and basic concepts of engineering [14]. One popular elementary engineering curriculum is the Engineering is Elementary (EIE) Program, which uses a five-step approach, described below, to lead students through the engineering design process. (1. Ask: define the problem and identify constraints; 2. Imagine: brainstorm ideas and choose the best one; 3. Plan: draw a diagram and collect materials; 4. Create: follow the plan and test it; 5. Improve: discuss possible improvements and repeat steps 1-5). By following the steps, using additional scaffolding when needed, children are engaged in the problem solving process that is at the heart of engineering design. These five steps are simple enough that even lower elementary school students can be actively involved in the engineering process [18].

Engineering design requires the linkage of (1) narrative discussion/description, (2) graphical explanations, (3) analytical calculations, and (4) physical creation, and the connection of math, science and technology can be present in the design processes. Hence, engineering design might serve to form motivating contexts to integrate the other three STEM disciplines. Te engineering design is meant to teach students that engineering is about organizing thoughts to form decision making for the purpose of developing better solutions and/or products for problems. Te knowledge and skills associated with the process of engineering design do not depend on the engineering discipline (e.g., mechanical, electrical, civil, etc.) and/or engineering science (e.g., thermodynamics, statics, or mechanics) that a particular engineering problem is related to. Design tasks entail developing critical thinking skills associated with engineering, technology, and science literacy [19].

Finally, we find that EIE’s model is advantageous for high school programs not only because of its wide adoption, but also because it uses simple terminology and scaffolds students by breaking down the steps. Thus, we used the EIE five – step engineering design process described in this article to instruct students to study.

The Engineering Design Process used in problem solving consist of:

(1). Identify a Challenge

(2). Explore Ideas

(3). Plan and Develop

(4). Test and Evaluate

(5). Present the Solution.

Engineering Design Challenges help students learn how to apply the problem solving approach used by Engineers.

Engineering Design Challenge Components

(1). Conditions: The setting, situation or context of the problem.

(2). Challenge: A clearly written challenge or problem statement that clarifies what students are required to do.

(3). Criteria and Constraints:

• **Criteria** relate to the challenge presented and are those things that must be followed or satisfied when completing the challenge.

• **Constraints** are typically limits related to the challenge or problem that must be followed.

(4). Resources: The materials, tools, or equipment that is provided or can be used to help solve the problem or complete the challenge.

(5). Evaluation: How the solution to the problem will be assessed & evaluated.

The design loop is a guide that helps make STEM design problems a more effective learning tool for students. It is a structure for thinking and doing—the essence of design and problem solving. Designing is not a linear process. When you design and make something, you do not think and act in separate, sequential steps. Rather, you complete activities that logically lead to additional activities--sometimes they occur in the order outlined below and sometimes they occur more randomly, but in almost all cases all of the activities outlined below occur during the engineering design process. It is a good teaching tool to require students to document their passage through all phases of engineering design. Below is an illustration and description of each phase of the design loop [20]

What is the problem? Identifying Problems and Opportunities

The first step is to define a real-world problem that meets your standards and content requirements, interests students, and has many grade appropriate pathways to success. The problem can lead to a process or a product solution as both are integral to the work of engineers. Central to the process of designing is the identification of a problem in need of a solution. On the surface, this appears to be a simple task, but it requires careful observation and a critical eye. The student designer will attempt to clarify, understand the specifications, and detail exactly what it is that they intend to do. At this point, the student begins to ask a number of questions (i.e., What are my limits? How much time do I have? To what materials do I have access?).

What do you want your students to be able to do before, during, and after the engineering design project? For example, to design and build water filter systems, they must know the physical and chemical properties of water and solutions; be able to work collaboratively to design, test, and re-design a process based on their prior and new knowledge; and present and defend their findings to their peers. Engineering projects ask students to look past content knowledge and towards the process of doing science and math and choosing appropriate technology. There should also be a focus on collaborative skills, metacognition (self-thinking and regulation), resiliency, and perseverance. Once you have chosen your performance criteria, you can design processes, rubrics, and checklists that you will share with students at the beginning of each project.

Brainstorming Solutions

In order to solve problems, all pertinent information must be gathered and documented for possible future reference. The importance of investigation and research cannot be over emphasized. Few solutions are new. Most new inventions involve many previously known principles and concepts. Generating a number of alternative solutions is one of the most important steps and often the most difficult to do. Although it seems to be human nature to latch on to your first idea and try and make it work. More ideas equal better solutions. Techniques: Brainstorming, sketching, doodling, attribute listing, and forced connection.

At this stage, all ideas are welcome, and criticism is not allowed. How creative can you be? What specific goal are you trying to achieve, and how will you know if you've been successful? What are some ways you can start tackling today's challenge?

Choosing Your Solution

Choosing the best among a number of ideas is less straightforward than it may appear. Two strategies: (1) Listing the attributes (good and bad points) of the ideas and comparing them; and (2) Developing a decision matrix that compares attributes to design criteria. The evaluation process may indicate a way to combine features of several solutions into an optimum solution. The student designer begins working on the myriad of sub-problems that need solutions. This involves modeling, experimentation with different materials, and fastening techniques, shapes, and other things that need to be done before actual construction of the final design is undertaken. At this point the student designer begins to develop models and prototypes that represent their idea. Two-dimensional and Three-dimensional models, computer models, and mathematical models are commonly used.

Test Your Solution

This may be as simple as applying the specifications to the end product to see if it does all the things that it is supposed to do [20]. This is where it's time to get creative! You've come up with a great, engaging problem and you know what you are looking for, so it's time to backwards design. Ask yourself these questions when designing your project: What is the problem? What STEM standards (NGSS, CCSSM, ISTE) does this problem align with? What background information do students need to solve the problem? What types of constraints will the students have (i.e. time, material, budget, etc.)? How will students work together to solve the problem? How will students test, gather data, and evaluate their products/solutions before redesigning? How will students share their results?

Evaluate Your Solution, Re-designing and Improving

This step involves performance testing, as in the case of a practical device. After evaluating the design, student designers begin implementing what they have learned from the evaluation—an effort to improve the product. Ask yourself these questions when designing your project:

Does your design meet the criteria for success? What is the hardest problem to solve as you build your project? Why do you have to do something a few times before it works the way you want?

Sharing solutions

All design problems should end with a culminating event. This could be a formal presentation of the production of the product or system. Ask yourself these questions when designing your project: What do you think is the best feature of your design? Why? What are some things everyone's designs have in common? What would you do differently if you had more time? What were the different steps you had to do to get your project to work the way you wanted?

2.3. Research on Water Purification Process

There are some researches on the following water purification process:

The research pointed out that the quality of water flows through the taps for drinking is gaining attention from public. There are still bacteria and minerals that exist in the tap water that can damage human's health. Hence, the objective of this work is to develop a personal, portable dual purposes handy water filter to provide an easier way to get safe, clean and healthy drinking water for human wherever they go. The designed system can be used in filtering water taken from public drinking fountains or other public water sources. The work is started by conducting a preliminary research. First, the constraints and criteria of the problem are identified and discussed in detail. Analysis of the mechanism performance is conducted as inputs for calculation, modelling, testing and other designing methods. Finally, several possible solutions of the problems are generated [21].

The development of a sustainable water supply can serve many needs around the world. Developing nations where conventional water treatments are not available require a sustainable water supply for their daily water needs. Sustainable water supply tools are ideal because of their minimal chemical usage, low start-up and operation costs, and the ability to be built economically for a small or large scale water supply. This project investigated the ability of a slow sand filtration (SSF) system to be a sustainable alternative to conventional drinking water treatment and also its' ability to provide high quality effluent. The SSF system consisted of a pretreatment stage that involved the use of three gravel roughing filters followed by a sand bed with a depth of 2.5 ft. The SSF system was provided with a continuous water supply to filter through the sand bed for approximately six weeks, with the effluent from the system collected twice daily. The effluent and raw water was then tested and compared to determine the ability of the SSF to improve the turbidity, pH, and the UV absorbance of the water [22].

2.4. Applying the Engineering Design Process to Organize High School Students in Vietnam to Design and Build Clean Water Filter Systems

Situation

Clean water is not available in all parts of the world. One of our most valuable and often overlooked resources is water. We can survive for a few weeks without food, but only a few days without water. Having clean water to drink is a luxury. Many people live with polluted water that is unhealthy to drink and bathe in. Have you ever wondered if your water is in a state of inability to drink? Can your family be infected from your own water source? In some areas in Vietnam, local people often use water that is not hygienic, such as water from wells, or ponds, rainwater, including river water for daily living. In addition, some areas are affected by severe droughts and saline intrusion. You decide to create a water filter at a low cost but quality is no less than a filter sold in the market to help habitants.

Challenge

Students are asked to design methods to filter water using ordinary materials, while also considering their designs' material and cost efficiencies. They learn about the importance of water and its role in our everyday lives.

Criteria & Constraints

Criteria: Each group of students will be given dirty water samples such as river water, ponds, alum water, saline water for filtering. Students apply engineering design process to design and build their own water filter system at as low a cost as possible. Then compare the results obtained after filtration with the quality water samples provided by the teacher.

Note that

you will receive points based both on the purity of the water that passes through your filter, as well as how fast your will pass through your filter. Water purity is weighted more, and should therefore be the focus of your thoughts.

You will also be evaluated on your attitude, team cooperation, time-management and overall contribution to your group.

Your design should consist of a simple sketch and a short paragraph describing why you used the materials you did, and how the order was chosen on the paper provided. Hand in the design to your teacher.

Discuss the details of your design to your class.

Constraints*:* Limit the cost of materials allowed for the design. Assign a price per unit of material and give students a budget to work within. Have students draw schematics of the layers. Once completed, give each team a sample of dirty water to start filtering in their water filtration system. Examine the results obtained according to the set objectives.

Resources (prompt)

Gravels, silica sand (quartz), activated coal, filter paper, plastic pipe fittings, hole saws, plastic bottles 2 liters, some pieces of cloth, pot, porcelain cup, plastic bag.

Disciplinary areas: STEM

Science: Models; Hypothesis Testing; Cause & Effect; Material properties; Empirical Evidence; Scientific Laws

- Ion exchange
- Reverse osmosis
- Microporous filtration
- Ultra-filtration
- Photo-oxidation
- Distillation
- adsorption

Technology: building systems; structures; foundations; prefabricated materials.

Engineering: Strength of Materials & Shapes; Structure & function; Stability; Models.

Math: Measuring; Geometry; Patterns; Scale.

Unit: Structures and parts of water filter systems

Standards:

Standards for Technological Literacy: Develop the abilities to apply the design process.

ELA Common Core Standards (writing): Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or expectations defined in the text.

Learning Objectives

Understanding of how filtration works.

Creative design methods.

Problem solving.

Mathematics (multiplication) reinforcement.

Teamwork to solve a challenge.

"Big Ideas"

Learning to use creativity for problem solving

Learning to use the concepts of the design loop

Technology is key in constructing water filter systems

Learning that science, technology, engineering, and mathematics all play an important role in developing water filter systems

Tools and techniques

Essential Question: Can you design and build water purification tools to help people have clean water for their daily lives?

Scenario: In some areas in Vietnam, local people often use water that is not hygienic, such as water from wells, or ponds, rainwater, including river water for daily living. In addition, some areas are affected by severe droughts and saline intrusion. You decide to create a water filter at a low cost but quality is no less than a filter sold in the market to help habitants.

Content: Water is the main component in our body. Human being body consists mainly of water (on average about 70%). Human being liver, for example, is about 90% water, brain 85%, blood 83% and even the bones 35%. Therefore, consuming enough water in our daily life is a must to stay hydrated and healthy. Water purifiers have become a necessity for every household. Water purifiers ensure that you get clean and safe drinking water on demand so that you stay away from water-borne diseases. There are different types of water filtration processes such as Reverse Osmosis Water Filtration (RO), Ultra Filtration (UF) and Ultra Violet disinfection (UV). You need to choose a water purification system depending on the quality of water. Water purification is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from water. The goal is to produce water fit for a specific purpose. Most water is disinfected for human consumption (drinking water), but water purification may also be designed for a variety of other purposes, including fulfilling the requirements of medical, pharmacological, chemical and industrial applications. The methods used include physical processes such as filtration, sedimentation, and distillation; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light. Purifying water may reduce the concentration of particulate matter including suspended particles, viruses, parasites, bacteria, algae, fungi, as well as reducing the concentration of a range of dissolved and particulate matter.

Teachers: Allow the students to do some research on water filter systems. There are many different types of water filter systems and they will need to consider their resources before designing their own.

Source: https://www.explainthatstuff.com/howwaterfilterswork.html.

Deliverables: Only use materials that are easy to find, low cost. Students or team of students must build water purification tools that can clean many kinds of dirty water.

Parameters: The completed water filter tool must:

Move from colored and odor water to odorless and colorless water; Turn saltwater into fresh water; remove alum from water

Be designed using the engineering design model

Be submitted to you with a completed brainstorming sheet and working drawing that illustrates how the structure was designed.

Teachers provide students with background knowledge for their design process. Teachers introduce the steps of the engineering design process that the students will use and provides them with the challenge (Ask): From the provided materials, build an water filter system that obtain pure water . Students work in teamwork, beginning their design phase by making and experimenting. This inquiry activity encourages students to imagine multiple ways to reach their goal before choosing a design to build. Additionally, they must explain their design and reasoning to their peers before they begin building. Once the model is built (Create), students engage in a cyclical process of test, redesign, and recreate to refine their model, while also noting changes on their drawing (Improve). Before the final test filter system, students explain their model to the class.

See Figure 1 The Design Loop For High Grades (K-10)

1. Ask the students "What is the problem? What are trying to fix or make better (improve)?

2. Have a class discussion on ideas. Have students work in groups to brainstorm ideas. Tell them to use a variety of resources: computer, library. Asking others questions, etc.

3. Tell each group to choose what they think is the best solution for the problem. Have student draw a sketch or blueprint of their solution. Ask students to think about these questions:

A. What will you need to build or create your solution?

B. How will you build it?

C. What problems or difficulties might you have?

4. Test your solution. Student will test their prototype.

5. Review your solution. Have students think about the results of their test.

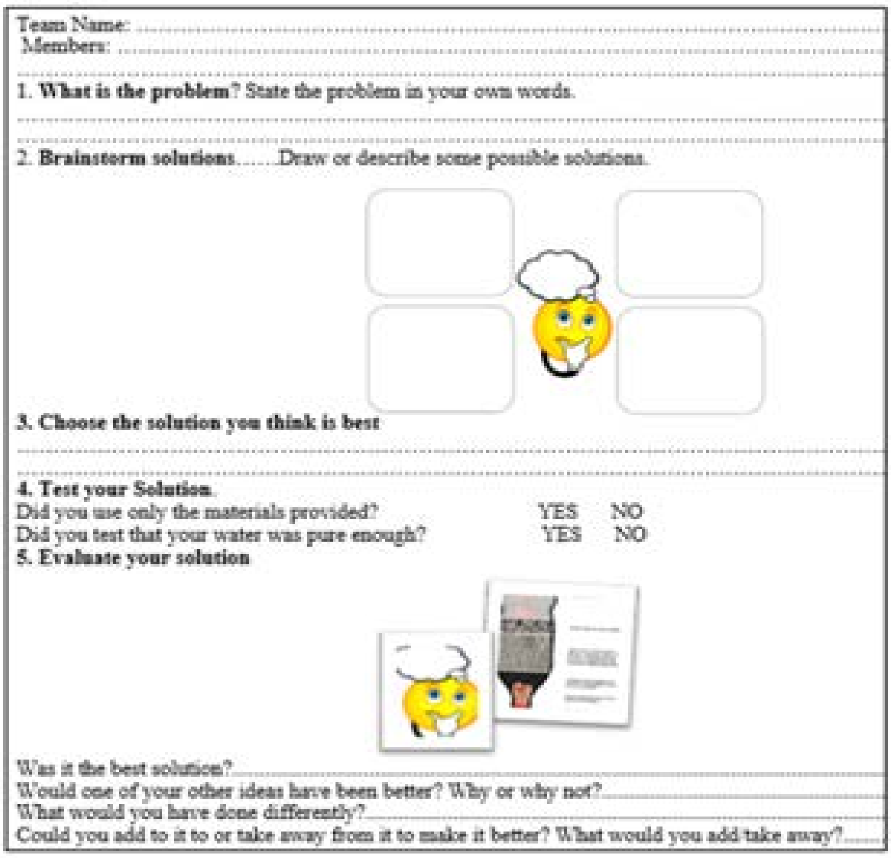
A. Was it the best solution?

B. What could they do differently? C. Can they add something or change something to make it better?

6. Present the problem and your solution. Have each group do a class presentation of their solution and the results.

Assessment

Self - assessment and peer- assessment based on the rubric, as shown in Table 1 and Table 2.


Team Name: ....
Members: ....

1. **What is the problem**? State the problem in your own words.

2. **Brainstorm solutions**...... Draw or describe some possible solutions.

3. **Choose the solution you think is best**

4. **Test your Solution**
Did you use only the materials provided? YES NO
Did you test that your water was pure enough? YES NO

5. **Evaluate your solution**

Was it the best solution?..........
Would one of your other ideas have been better? Why or why not?..........
What would you have done differently?..........
Could you add to it to or take away from it to make it better? What would you add/take away?..........

Figure 1. The design loop for high grades (K-10)

Table 1. Assessment Engineering Design Process in fabricating water filter systems

Criteria for Assignment	No Evidence 0	Limited Understanding 1	Some Understanding 2	Good Understanding 3	Comprehensive Understanding 4
The problem was restated in his/her own words. (Design Loop #1)					
Brainstorming included more than one idea. (Design Loop #2)					
A solution was created with a sketch of the design (a blueprint). (Design Loop #3)					
A water filter tool used only materials from the "store' and check that your water was pure enough. (Design Loop #4)					
Student completed the data sheet for all water tools tested.					
Student evaluated how he/she could make it better next time. (Design Loop #5)					

Table 2. Water Filtration Rubric

CATEGORY	4	3	2	1
Water Quality	Very clear, no particles	Clear, some small particles remaining	Murky, large particles remaining	No noticeable change from start
Attitude	Never publicly critical of the project or the work of others. Always positive about the task(s).	Rarely publicly critical of the project or the work of others. Often positive about the task(s).	Occasionally publicly critical of the project or the work of others. Usually positive about the task(s).	Often publicly critical of the project or the work of others. Often negative about the task(s).
Team Cooperation	Almost always listens to, shares with, and supports the efforts of others. Tries to keep people working well together.	Usually listens to, shares, with, and supports the efforts of others. Does not cause "waves" in the group.	Often listens to, shares with, and supports the efforts of others, but sometimes is not a good team member.	Rarely listens to, shares with, and supports the efforts of others. Often is not a good team player.
Time-management	Routinely uses time well throughout the lesson to ensure things get done on time. Group does not have to adjust deadlines or work responsibilities because of this person's procrastination.	Usually uses time well throughout the lessons, but may have procrastinated on one thing. Group does not have to adjust deadlines or work responsibilities because of this person's procrastination.	Tends to procrastinate, but always gets tasks done by the deadlines. Group does not have to adjust deadlines or work responsibilities because of this person's procrastination.	Rarely gets tasks done by the deadlines AND group has to adjust deadlines or work responsibilities because of this person's inadequate time management.
Contributions	Routinely provides useful ideas to the team. A definite leader who contributes a lot of effort.	Usually provides useful ideas to the team. A strong group member who tries hard!	Sometimes provides useful ideas to the team. A satisfactory group member who does what is required.	Rarely provides useful ideas to the team. May refuse to participate or give up at times.

2.5. Result

Divide students into 3 groups.

2.5.1. Group 1: Filtering Well Water

Learn the toxic components of well water

Chemical contamination is a common problem with groundwater. Nitrates from sewage sludge, fertilizer or sewage are a particular problem for babies and young children.

Pollutant chemicals include pesticides and volatile organic compounds from gasoline, dry-cleaning, the fuel additive methyl tert-butyl ether (MTBE), and perchlorate from rocket fuel, airbag inflators, and other artificial and natural sources. Several minerals are also contaminants, including lead leached from brass fittings or old lead pipes, chromium VI from electroplating and other sources, naturally occurring arsenic, radon, and uranium—all of which can cause cancer—and naturally occurring fluoride, which is desirable in low quantities to prevent tooth decay, but can cause dental fluorosis in higher concentrations.

Some chemicals are commonly present in water wells at levels that are not toxic but can cause other problems. Calcium and magnesium cause what is known as hard water, which can precipitate and clog pipes or burn out water heaters. Iron and manganese can appear as dark flecks that stain clothing and plumbing, and can promote the growth of iron and manganese bacteria that can form slimy black colonies that clog pipes.

Investigating well water purification procedures in some rural families in Vietnam

Below are some pictures of students visiting the water purification system of the households (see Figure 2).

Figure 2. Investing well water purification procedures in some rural families in Vietnam

Students plan, sketch, design, evaluate, redesign their water filter system from materials supplied (see Figure 2, Figure 3 and Figure 4).

Figure 3. Materials (plastic bottle, well water, gravel, sand, activated carbon)

Figure 4. Water filter system

Students carry out filtering well water contaminated with alum and get results (see Figure 5 and Figure 6).

Figure 5. Pour well water into the filter system

Figure 6. Water obtained after filtration (cup in the middle)

2.5.2. Group 2: Filtering Dirty Water

Students plan, sketch, design, evaluate, redesign their water filter system from materials supplied (see Figure 7, Figure 8, Figure 9 and Figure 10).

Figure 7. Materials

Figure 8. Design and construction of water

Figure 9. Sort the filter materials and carry out filtering dirty water

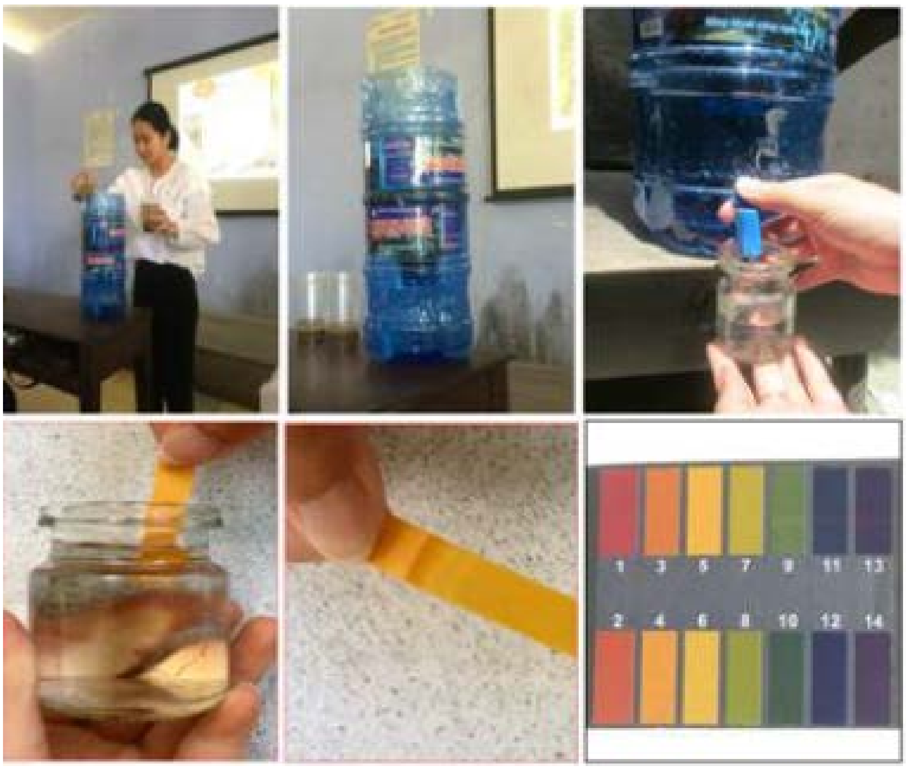


Figure 10. Get results after filtering

Figure 11. Materials (seawater, pots, porcelain cups, plastic bags, lanyards, stones)

Figure 12. Carry out filtering water

2.5.3. Group 3: Filtering Saline Water

Students plan, outline, design, evaluate, redesign their water filtration system from materials they find themselves (see Figure 11, Figure 12 and Figure 13).

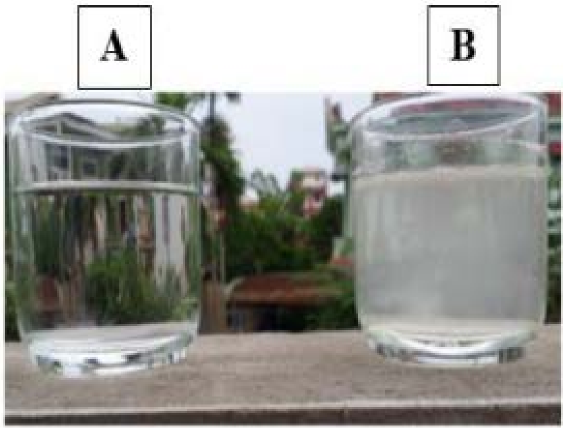


Figure 13. Get results after filtering: Cup (A): After filtering and Cup (B): Seawater

3. Conclusion

We have organized for 36 K-10 students in Vietnam to apply the engineering design process to a specific project. That is design and built filter systems some type of water to meet the clean water need for local people as at as low a cost as possible. Obtained results: (1) Students participated actively in activities. (2) Students actively plan, brainstorm, design, build, re-design, reconstruct their systems to be appropriate and effective. (3) Students developed much competencies in the 21st century. We value the mentality, attitudes and experiential products of our students. Hence, Engineering-based problems, with their inbuilt design requirements and couched within real-world contexts, have the potential to foster this learning in young students.

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