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APPLYING STEM ENGINEERING DESIGN PROCESS THROUGH DESIGNING AND MAKING OF ELECTROSTATIC PAINTING EQUIPMENT IN TWO RURAL SCHOOLS IN VIETNAM

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ABSTRACT

STEM education has been emphasized in Vietnam's new National Education Curriculum to develop students' capacity and prepare for the modern labor market. However, there are concerns that STEM education may not be suitable for low-budget or rural schools, where the conditions are insufficient. This research aims to investigate the possibility and efficiency of applying STEM education, focused on the Engineering Design Process (EDP), in rural high schools in Vietnam. This paper reported the results of two rounds of research on 96 grade 11 rural students who participated in a STEM project of designing and making electrostatic painting equipment using the EDP as the alignment. The students were from two rural schools of Thap Muoi district, Dong Thap province in Mekong Delta, where education was considered lower than the general standard of Vietnam. Data was collected using qualitative research methods, including teacher's observation and notes for the whole process, students' portfolios (worksheets, research diary, diagram and pictures, video clips, messages, and notes), and informal interviews. Triangulations were applied during data collection and analysis. The results showed promising where the students actively engaged in all the stages of the EDP and could accomplish all the requirements. Moreover, compared to round 1, round 2 showed slightly better indicators which means the experience of the teacher is improved the students' achievement. Therefore, it can be concluded that STEM EDP can be applied with encouraging results even in rural schools.

Keywords: engineering design process; rural schools; STEM education; Vietnam

INTRODUCTION

Recently, many Governments intensively focused on the role of Science, Technology, Engineering, and Mathematics (STEM) education for their future economic prosperity and as a solution for global problems such as global warming, energy, and water resources, food security, and others (Cooper & Thong, 2019). The industrial revolution in the 21st-century demands more skillful laborers in STEM majors. Indeed, STEM education has been becoming a "global trend" thanks to the practical benefits it can bring to learners and suit the labor needs of the new era (Ritz & Fan, 2014). STEM was first officially highlighted by the Vietnam Ministry of Education and Training (VMoET) as an education orientation in an Official Letter on Guiding the implementation of secondary education tasks for the academic year 2014-2015 (VMoET, 2015). In 2016 and 2017, the British Council conducted a comprehensive STEM education program at fifteen Vietnamese high schools under Newton Fund and VMoET. The program has made a tremendous impact that can be seen through activities and improvements in educational methods at schools (Duc & Hoa 2021). From this success, in 2018, VMoET issued a national educational reform aiming to develop

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students' capacities and quality, which indicated the importance of applying STEM in education, in which Maths, Science, Natural Sciences, Physics, Chemistry, Biology, Technology, Informatics have to be linked to implementing STEM education (VMoET, 2018). It aims "to help students apply knowledge of science, technology, engineering and math to solve practical problems in a specific context" (VMoET, 2018). Therefore, STEM education in Vietnam is not optional anymore. However, a compulsory part of the National Education Curriculum and were introduced to teachers in many conferences and workshops held by VMoET, for example, the workshop "STEM Education in the New High School Program" (VMoET, 2017) or "Promoting STEM education in high schools" (VMoET, 2020). However, applying STEM in the Vietnam context has many difficulties. Two of the main reasons are that Vietnam's education system still lacks sufficient financial support, and Vietnamese teachers still do not have much experience in STEM teaching and learning (Nghia & Tran, 2020).

Also, Le et al. (2021) conducted a qualitative study at ten high schools (grades 10–12) in a central Vietnamese province to gain in-depth insights into the experiences and beliefs of high school teachers regarding STEM education and reported the main four challenges: 1) Inadequate teacher preparation for STEM integration; 2) Lack of a curriculum framework, teaching materials, and assessment guidelines; 3) Teachers' beliefs about STEM integration; and 4) Limited equipment, resources, and rigid school structure. The first three challenges were intensively concentrated on in most VMoET STEM workshops to improve STEM education in Vietnam, yet the last one is a big challenge because Vietnam is still a developing country, where the budget for equipment and resources in education is generally inadequate.

One of the main STEM teaching orientations is the Engineering Design Process (EDP), a form of Design-based learning (DBL), as reviewed by Hafiz & Ayop (2019). Design-based learning is a form of learning in which students learn what they need to learn in a moderate amount of time while designing something (Lim et al., 2012). Usually, the process can be spread over time. For example, for simple problems, students can concentrate on solving them within a lesson, but for more complex problems, students can study for a longer duration. Therefore, depending on the level of knowledge, teachers can direct students to each corresponding problem level, ensuring that students can still solve the problem and the amount of knowledge is still adequate. In STEM education, EDP is "a pedagogical strategy that requires students to follow a set of steps to create the most effective solution that is iteratively tested and justified by the mathematical and scientific concept" (Hafiz & Ayop, 2019). Related to current Vietnamese education movements, STEM EDP can be practiced in the form of Project-based Learning, Case-based Learning, or Experiential Learning.

Teaching and learning STEM through the EDP will simulate the process of engineers solving a technical design problem. There are pretty many suggestions to perform EDP. For instance, Berland et al. (2014) presented a four-step EDP, including (1) defining problem; (2) generating and selecting between multiple possible solutions; (3) modeling and analysis; and (4) iteration. Nevertheless, this research employed a five-stage EDP as proposed by Han & Shim (2019), including: (1) defining problem; (2) in-gathering information; (3) generating the solutions; (4) implementing the best solution; and (5) evaluating the solution and reflecting because this model is fitted with the aims of this research where the "iteration step" would not be applied for the same group but the next round, in next school year.

In short, STEM EDP can encourage creativity in designing and manufacturing applied knowledge for life. Particularly, students will have more chances to apply STEM knowledge and competency in solving problems in real-life applications instead of focusing on the knowledge of the subject matter but neglecting the application (Lin et al., 2020; Sumarni et al., 2021). This is also the aim of Vietnamese education reform recently. However, there are concerns about applying STEM EDP in Vietnam, a developing country with a limited fund for STEM education, especially in rural areas, as reviewed by Goodpaster et al. (2012) and Mutambara & Bayaga (2021). Several researchers have found this a gap in STEM research, as illustrated by Dinh (2021). She explored the difficulties in implementing a STEAM education model at the Northern mountainous preschool in Vietnam. However, there are no academic articles about applying STEM education in rural Vietnam high schools to the best knowledge. Therefore, this research aims to investigate the possibility and efficiency of applying STEM education, focused on the Engineering Design Process, in rural high schools in Vietnam. The research was conducted in two rural schools of Thap Muoi District, Dong Thap Province, Mekong Delta region, where education is generally considered lower than the average standard of

Vietnam. So far, Vietnam's Mekong Delta region was called the "low-lying areas in terms of education and training" by VMoET (VMoET, 2019).

METHODS

Aligning to the aim to have the best insights into the possibility of applying STEM education in Vietnam countryside schools, then to encourage change in teaching, this study focuses on qualitative data to "understand a phenomenon by focusing on the total picture rather than breaking it down into variables." as considered by Ary et al. (2010). Moreover, "qualitative research is best suited to address a research problem in which you do not know the variables and need to explore" (Creswell, 2012) which is the case of this study. This research was designed based on the grounded theory offered by Glaser and Strauss (2009), in which theory will be developed based on the data obtained instead of comparing with reasons pre-existing theory. The more data was collected for that design, the better to explore the problem and form a more comprehensive understanding. Therefore, data collection was conducted as much as it could during the process. At each stage, data were collected using different methods, including using: teacher's observation and notes for the whole process; students' portfolio (worksheet, research diary, diagram and pictures, video clips, messages, and notes); and informal interview by follow-up questions during and after the process to deeper investigate students' opinions as well as to correctly interpret their understanding.

To assess students' level of understanding and the ratio of students' engagement in each EDP stage (which will be presented in detail later in the next part and Table 3), besides information from the previous methods of data collection, the students also used an analytic rubric with the answers range from "limited," "fair," "good," and "excellent" to assessed themselves after the task. The statements in the rubric include two main categories: First, understanding of the task: (a) I clearly understood the research problems before taking the task; (b) I clearly understood the structure and operation principle of electrostatic painting equipment; (c) I clearly understood the advantages and disadvantages of electrostatic painting equipment. Second, level of participation in each stage of the task: (a) I actively participated in the information gathering process to understand the problem; (b) I actively participated in the problem-solving process to find solutions; (c) I actively participated in discussions to find the best solutions; (d) I actively participated in the manufacturing process and operating experiments; (e) I actively participated in presenting, evaluating the solutions, and reflecting.

There was no grading pressure for this activity to ensure that the students would give the most honest assessment. The results then were compared with the teacher's interpretive reflections from observation and students' products. The answers from "good" and "excellent" were summed up to indicate that the student clearly understood the problems. Noted that the researchers considered that if the student chose "fair" for these statements, that means they still have "something unclear." The answers from "fair" to better were used to indicate that the students have engaged in each stage.

Nevertheless, the results were aligned with team assessment and researchers' observation to modify the final ratio. For example, if a student assessed himself as having "fair" participation in the "information gathering process to understand the problem," researchers will compare the response with his group leader's opinion to ensure that the result was correct. The teacher can also use his observation and notes to strengthen the conclusion. Guides for each stage were openly explained to the students who participated in the research to ensure every participant understood the requirements before doing the task. There is a note for students that the product will be highly appreciated if using inexpensive and recycled materials as it is vital to be reproductive on a larger scale at other rural schools in Vietnam, where the budget for STEM activities is minimal, or even there is no budget for such activities at some schools.

Investigator triangulation was used to make sure the inferred information is not from the perspective of an individual. Investigator triangulation is one of the research strategies to guarantee the trustworthiness of the data interpretation, as addressed by Ary et al. (2010). Also, applying several types of triangulations makes the qualitative data have better credibility, as pointed out by Cohen et al. (2007). One of the researchers is the high school teacher at Thap Muoi Upper Secondary School, one of the schools where the research was conducted. Therefore, it was pretty effective for him to collect the data not only from the viewpoint of the researcher but also from that of the teacher, using teacher-student forums and conversations. The other researchers are observers. Each researcher independently analyzed and interpreted the collected data, then compared it together and discussed it in commons. If there were undefined data, the teacher-as-researcher would make more casual conversations with the students to gain more information.

Each school year, the participants were 48 grade 11 students at two rural schools, as described in Table 1. These schools are located in the Thap Muoi district, 32 km away from Cao Lanh city, Dong Thap Province, Vietnam's Mekong Delta. Most of the students are from farmer families with low economy and do not have much access to information technology in learning; most of their families did not/could not concern much in their children's education since the parents do not have proper education (most of the parents only finished primary school education). The context of rural schools in Vietnam is quite similar to that of other countries, for example, Indonesia, as the students are generally considered lower than the urban schools in science process skills (Tanti et al., 2020) and also lower in students' attitudes in science subjects (Astalini et al., 2020). For this, if the STEM DBL success in these settings, it positively can be a success in other better contexts.

The classes were selected randomly, while the participants were selected by letting the students volunteer to join this extra-curricular learning activity. Typically, each class had more than 20 registrants, more than half of the class members. However, only 12 students in each class were selected to be arranged in two groups, with each group having two good, two fair, and two average graded students. Each school year had eight groups working in two different schools from this sample selection procedure. Noticeably, there were only one or two girls in each group, indicating that Vietnamese female students still hesitated to join in STEM activities. This is, however, not surprising, as many researchers have shown the lack of women in STEM courses (Herrmann et al., 2016) or that "the gender gaps in STEM start well before women enter the workforce" (Kijima et al., 2021).

Table 1. Information of the Samples

School year	School	Class	Number of participants	Number of groups
2018-2019 (round 1)	Thap Muoi Upper Secondary School	11A2 and 11A3	24	4
	Doc Binh Kieu Upper Secondary School	11CB1 and 11CB6	24	4
2019-2020 (round 2)	Thap Muoi Upper Secondary School	11A2 and 11A3	24	4
	Doc Binh Kieu Upper Secondary School	11CB4 and 11CB7	24	4
Total			**96**	**16**

Note: A school year in Vietnam starts from August to May next year.

The paper employed a practical action research design as this is considered "the most applied, practical design... to explore a practical problem with an aim toward developing a solution to a problem." The employment aims to experiment with STEM EDP learning in schools with a low financial condition, which involved high school students in team-based STEM EDP in increasing their practical applications of knowledge and skills, together with teacher-as-researcher development (Creswell, 2012). The action plan was conducted in the form of a project with the task of designing and constructing a set of electrostatic painting equipment. The research included two rounds in two school years to ensure that the results were reliable and replicable. Details of each stage can be found in the following parts.

First of all, the teacher himself designed and made handmade electrostatic painting equipment before teaching so that he could understand well how to design, construct the device, and estimate the level of the task's difficulty, to make sure that the task was in the students' zone of proximal development as suggested by Vygotsky (Smagorinsky, 2012). The teacher-as-researcher then shared his own experience with the research team. The "preparation stage" was not included in the main STEM EDP stages, yet was very important to make sure the action plan was effective and ran smoothly. From that, the learning activities were designed based on the EDP of Han & Shim (2019), with details as the following:

Stage 1: Defining problems. Study challenge summary: "You need to help your family paint the metal doors of your house with oil paint. However, the weather in the South of Vietnam with high rainfall ratio makes them easy to be rusted. You read in a newspaper about an electrostatic spray gun and want to use it to paint the doors, yet the equipment's price is too high. How can you make a set of electrostatic painting equipment by yourself?". Research problems for students: -What is the scientific structure of electrostatic painting equipment, and how can it effectively cover the material surface?; -Construct a set of electrostatic painting equipment with recycled material and little money. At the end of the lesson about electrostatics, this stage was conducted in a five-to-ten minute discussion in grade 11 physics class in Vietnam to engage students in solving daily life problems using scientific concepts. Then the teacher guided the groups on how to gather information and investigate the problem at home in stage 2.

Stage 2: Ingathering information. After the lesson, the students had three days to find information, investigate the scientific structure of electrostatic painting equipment, and effectively cover the material surface. In class, students presented their findings and learned new knowledge. Generally, each class (four groups) took ten to twenty minutes to finish the presentation. Guidance questions are: 1. What is the structure of electrostatic painting equipment?; 2. What are the main parts of that electrostatic painting equipment? ; 3. Report the operation principle of electrostatic painting equipment; 4. Draw the structure diagram of the electrostatic painting equipment; 5. What are the advantages and disadvantages of electrostatic painting equipment?.

Stage 3: Generating the solutions. Students worked in groups to make a plan to design and manufacture electrostatic painting equipment so that the ideas were not duplicated. When necessary, some suggestions were provided, including intended device size, type of equipment, structure, operation, intended plan, time, money, teamwork activities, tasks for each member, and others. Each group had 20 minutes in class to discuss the design structure. After that, each group briefly presented their designed structure, operation principle, and plan to make it. It was noted that they had learned about electrostatic painting equipment only through the internet and did not see real devices. Teachers asked provoking questions to help students consider their plan before construction and recommended students propose diverse and rich solutions.

Stage 4: Implementing the best solution. After stage 3, the students had approximately two weeks to construct their devices both at school and at home. Notably, they worked together and with the teacher at school three times per week (each time is around 2 hours) in their arranged free time. The teacher aided and assessed the student's work at home by using Zalo group, direct calls, or messages and checking the group's portfolio and report. The teacher only gave limited guides to avoid losing students' creativity or framing their thinking.

Stage 5: Evaluating the solution and reflecting. After two weeks of making, each group presented their equipment and the manufacturing process, then tested the device in front of the class. Students make a report in the form of a PowerPoint presentation in which they briefly present: Their ideas, principle, and structure of their device; Their experience in manufacturing activities with pictures and clips; Results of the pilot test on metal and evaluate the effectiveness of their device; The evaluation of the contributions and acknowledgment for each team member.

After the presentation, the teacher showed his handmade device to let the students invest more profound in the structure and principle of working. This can be considered a modification of this stage, where students can compare and contrast their devices with a "more professional" device. Hence, they could have more profound insights into the problem and reflect more effectively with the teacher's aid. Thus, this step was highly recommended for STEM EDP learning.

Follow-up questions after students' presentation can be asked if necessary, includes: Where did you find the necessary information?; What are the difficulties in the manufacturing process?; What improvements did your group make compared to existing devices?; What experience did your group gain in the manufacturing process?; Point out the creative points in the product manufacturing process ; Compare your device with the sample of the teacher. How can you improve your current device?; What have you learned through these extra-curricular activities?

Noted that during the whole EDP, students were asked to write their group's research diary for each stage and store the evidence of their work, such as writing down each members' opinions, difficulties and solutions, taking photos and video clips, drawing diagrams, then arranged them to make their group's portfolio. Researchers used formative assessment based on each group's manufacturing diary, video clips of the process of making, students' opinions, and presentations to evaluate students' activeness and creativity, then compare with the student's self-assessment. The summative assessment was also by teachers, researchers, and students, to assess the final product and presentation. Total teaching time in class, including students' presentations, for each school and each year range from 90 minutes to 120 minutes.

RESULTS AND DISCUSSION

The learning activities were conducted as described and indicated promising results: (a) thanks to the experience of making the device by himself, the teacher could anticipate the difficulties of students to advise and guide effectively; (b) students had not seen the real device. They had many creative ideas rather than being framed to the normal products; (c) although not all the participants had sufficient conditions to do the task, they willingly joined together at a friend's house with a smartphone and internet. The parents were also mentally supported the students in the project. Luckily, smartphones and the internet is becoming relatively common in most regions of Vietnam, even in the rural and mountainous regions; (d) the five stages of EDP were easy and suitable to be applied in STEM Design-Based Learning; (e) through two rounds, students made: First, sixteen designs which each group successfully had their design. A sample of the paint-gun is shown in Figure 1. The handwriting in Vietnamese indicates the role of each part of the gun in the diagram.

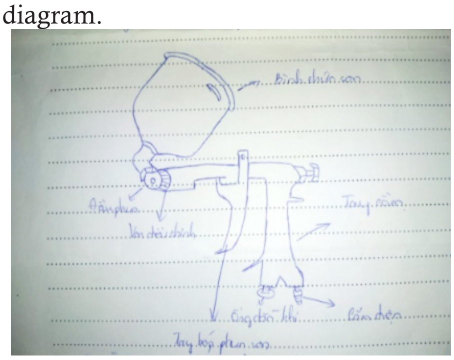

Figure 1. A Sample of Students' Electrostatic Painting Equipment Design

Second, ten real and inexpensive devices. Four groups in round 1 and 2 groups in round 2 could not finish their real product from the designs because of several reasons such as lack of suitable material and wrong ways of manufacture. Some are shown in Figures 2 and 3. Figure 2 presents several gun-heads that the students handcrafted. They are variable in the material and designs. All of them were made from recycled material and things that the students found at home and local recycled stores.

Figure 2. Some Samples of Students' Electrostatic Spray Guns

Figure 3 demonstrated a complete set of students' electrostatic painting equipment, including a spray gun, a pump, and a box to place the object to paint. The high voltage power source was from Van De Graff electrostatic generators, which produced another STEM project of the same group of researchers. Detailed information about this type of electrostatic generator can be found in Ghosh (2021). The pump was shared in groups to minimize the cost of the project.

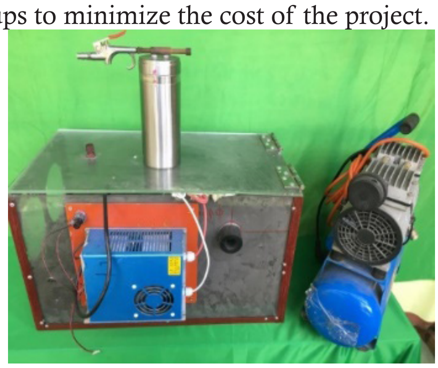

Figure 3. A Complete Set of Students' Electrostatic Painting Equipment

The students then pilot-paint some small metal materials, as seen in Figure 4. Students were asked to wear insulated gloves when they operated the equipment. In the whole testing process, the students themselves did the installation and testing and explained their work to friends and the teacher. Not all the devices effectively worked at this stage. 1/4 (25%) and 1/6 (17%) of the handmade devices were broken or not working during this process in rounds 1 and 2, respectively. Nevertheless, the students could identify the flaws of their devices and propose ways to mend them. Thus, students and the teacher both learned from success and failure.

Figure 4. A Group of Students Ran Their Equipment to Paint the Object

Tested result: The material was well-painted with a smooth surface and durable, as shown in Figure 5. Some painted samples were unsatisfied as the spray paint was not smooth due to the ineffective air blow designs.

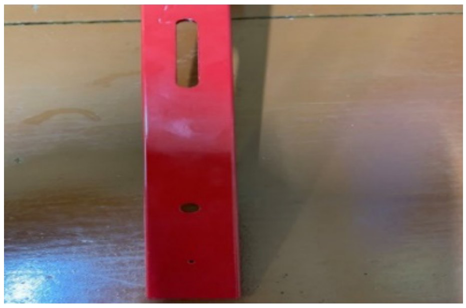

Figure 5. A Sample Tested Object

The general summative data includes statistics numbers on average manufacturing time, testing time, cost, and rate of groups that failed in manufacturing the equipment; equipment is broken, and unsatisfied painted samples from the electrostatic painting equipment EDP project in the two rounds were summarized in Table 2 for a comparison.

Table 2. General Information from the EDP of Students' Homemade Electrostatic Painting Equipment

Criteria	Results	
	Round 1 (2018-2019)	**Round 1 (2019-2020)**
The average manufacturing time for one set of equipment (not including time for designing)	8 hours	6 hours
Structure of students' handmade electrostatic painting equipment	Simple and diverse with many details made from recycled things; have high aesthetics; moderate size.	
Rate of groups failed in manufacturing the equipment/ total groups	50% (4/8 groups)	25% (2/8 groups)
Equipment broken rate when operating experiment	25%	17%
Rate of unsatisfied painted samples	10%	5%
Average time to operate the equipment to paint a sample metal stick	6 minutes	4 minutes
Cost to make a set of electrostatic painting equipment (not including the Van de Graff electrostatic generator)	300,000 VND (~13,6 USD*)	250,000 VND (~11,4 USD*)

* Note: The currency exchange rate was applied at the related time when the students bought material.

It is clear from Table 2 that this extra-curricular STEM activity did not cost too much time, effort, and money of the students and teacher, which makes it possible to reiterate on larger scales. The students exposed their creativity through the designing and making equipment process. They can make a simple and effective electrostatic spray gun with only cheap and recycled materials. However, at the first round in the school year 2018-2019, the ratio of groups who failed in Stage 4-"Implementing the best solution" was high (50%). One of the reasons is that the teacher did not have enough experience in guiding the students to find out and correct their mistakes. This failure rate decreased significantly in the next school year to 25%, thanks to Stage 5-"Evaluating the solution and reflecting" of round 1 and teacher's improved experience. The rate of equipment was broken when operating the experiment. The rate of unsatisfied painted samples also decreased in round 2. This is not surprising, as teacher pedagogical content knowledge was long confirmed to significantly impact students' academic achievement (Jacob et al., 2020). This is also evidence of the effectiveness of Stage 5, both on students and teachers. This is quite similar to the results reported by Toto et al. (2021), where science teachers' understanding and readiness in implementing STEM were improved through implementing STEM in their teaching. Another implication is that teachers' knowledge and skill are vital to successfully organizing STEM activities because teachers "play a critical role in the success of new reforms," as Nugroho et al. (2019), yet teacher STEM pedagogical content knowledge will be developed through real teaching experience. One major limitation was that the box to place the object to paint was relatively small, so the students could only test on small metal objects. Nonetheless, the students had confidence and self-awareness that they could manufacture a product that they could use in real-life applications.

The recording and analysis of both project rounds showed that the most important stage of developing students' creative ability was Stage 3: "Generating the solutions." This is when students actively discussed and gave their own opinions about the device, such as determining its knowledge and choosing models and materials to make the device. Students gave many creative ideas, such as charging the paint powder with Van De Graff's electrostatic generator, making a pressure booster circuit, or making a paint spray gun from many different materials.

Information in Table 3 was collected using students' self-assessment, teacher's and researchers' observation, students' activity portfolio of each group, and the group leaders' general reports as mentioned previously with consensus results. Consequently, it can be concluded that the students could assess themselves accurately when they did not have the pressure of marks or grades. It was clear that many students actively participated in every stage of the EDP and had a good understanding of the problems. There were only several average-graded students who still claimed that they "fairly understand" the research problems as well as the structure and operation principle of electrostatic painting equipment. None of them claimed a "limited" understanding of this research subject matter knowledge.

Table 3. Ratio of Students' Engagement in Each EDP Stage Through Designing and Making Electrostatic Painting Equipment

Criteria	Results	
	Round 1 (2018-2019)	Round 1 2019-2020)
Percentage of students clearly understood the research problems after stage 1.	88% (42/48)	90% (43/48)
Percentage of students clearly understood the structure and operation principle of electrostatic painting equipment.	83% (40/48)	88% (42/48)
Percentage of students clearly understood the advantages and disadvantages of electrostatic painting equipment.	100% (48/48)	100% (48/48)
Percentage of students participated in the information gathering process to understand the problem (stage 2).	94% (45/48)	96% (46/48)
Percentage of students participated in the problem-solving process to find solutions (stage 3)	85% (41/60)	92% (44/48)
Percentage of students participated in the discussion to find the best solutions (stage 3)	75% (36/48)	83% (40/48)
Percentage of students who participated in the manufacturing process and operating experiment (stage 4)	77% (37/48)	94% (45/48)
Percentage of students participated in presenting, evaluating the solutions, and reflecting (stage 5)	50% (24/48)	60% (29/48)

The lowest participation rate is in stage 5 (50% in round 1 and 60% in round 2). Nevertheless, this is not surprising due to the culture of Vietnam usually making students shy to express their ideas, as indicated somewhere else (Thao-Do & Yuenyong, 2017). The 50% to 60% rate of students' engagement in presenting and reflecting is not a bad result in Vietnam. In fact, during students' presentations, students dare to ask questions or give suggestions and compare their friends' equipment to their one, then suggest revising the design to make it more effective.

Almost all of the students participated in the information-gathering process to understand the problem (94% - 96% for rounds 1 and 2, respectively). However, the stage that caught their enthusiasm were stages 3 and 4. Generally, the members of the group participated most actively in the "problem-solving process to find solutions" and "discussion to find the best solutions" (stage 3) (85%-92% and 75%-83% for round 1 and 2, respectively), and the "manufacturing process and operating experiment" (stage 4) (77%-94% for round 1 and 2, respectively). Especially in stage 4, the students were very active in the recommendation of manufacturing materials and searching for materials. They went to many equipment stores and scrap stores to find a variety of materials such as air guns or water guns. They also found and used recycled bottles, pipes, tin cans, and kinds. Some groups had to make 4 to 5 times before success, but they were still eager every time. Generally, all the groups were always ready to discuss and exchange ideas whenever a new idea came to their minds. When successfully made the equipment, the whole group also actively discussed how to make a good report and presentation on the electrostatic painting equipment and their making process. Some students did not join the discussion much. Instead, they listened to their friends and helped their friends prepare the materials.

Another interesting result was also significant. To select the participated volunteers for the project, 345 students of the eight selected classes had answered the question: "Are you interested in participating in the production of experimental equipment?" and the answer was 5% "Very interested in," 55% "Interested in," and only 7.5% "Not interested in." This implied that most Vietnamese students in rural schools, both boys and girls, were keen on STEM EDP. Nonetheless, very few girls joined the projects. Stakeholders should consider this to improve female attendance on STEM by encouraging them more and giving better aid for female students.

It can be concluded that the STEM EDP on the designing and making of electrostatic painting equipment has achieved the following results: students were active and interested in almost every stage of the process; students know how to exchange their ideas, make hypotheses and implement hypotheses, practice practical experiment skills and creative thinking. This is evidence for the possibility of applying STEM EDP in education in rural schools of developing countries such as Vietnam, which can increase students' practical experimental skills and creativity. This STEM activity can develop students' creativity and improve their collaborative abilities. Especially with a limited budget, students can promote their creativity and problem-solving skills even better than expected.

CONCLUSION

STEM Engineering Design Process can be easy to apply at low cost yet brings noticeable results in these rural schools in Vietnam. The result is promising where many students (more than half of each class member in the two examined schools) wanted to join the project in the sample selection phase. This indicated that most students in these two rural schools were interested in the STEM EDP project. All the participants, including the average graded students, actively engaged in EDP stages and learned from both their friends' success and failure. They demonstrated their creativity in applying school knowledge to practical applications in life. These skills are highly appreciated in Vietnam's New National Curriculum in particular and in every educational system. Moreover, after round 1, round 2 showed slightly better indicators which means the experience of the teacher is improved the students' achievement. Educators and stakeholders can consider developing detailed curricula for schools in Vietnam and other countries with similar contexts.

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