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Automatic Trash bin Arduino Project (ATAP): Enhancing Computational Thinking Skills through STEM Learning

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Abstract

Computational Thinking is nowadays the fifth of twenty-first-century skills for every individual. Two main approaches to enhance Computational Thinking Skills (CTS) are computer-based and unplug activities. In this study, computer programming exercise was embedded in STEM Learning Using Automatic Trash bin Arduino Project (ATAP). Observations of student's activities, products, and students' worksheets were collected and analyzed in accordance with Portfolio assessment rubric consist of some indicator and criteria to get the figuring of student's computational thinking skills. Based on the data, there are enhancement of Computational Thinking Skills (CTS) during the lesson of ATAP STEM Learning. The CTS was getting better enhancement are abstraction, pattern recognition and decomposition but algorithm design were considered need more time to practice. In addition, the results showed that learning cognitive outcomes with normalized gain <g> valued at 0.66 with average category. These indicates that STEM Learning Using ATAP have positive effect to enhance learning effectivity and Computational Thinking Skills. But there are still need many improvement especially in learning material like module, worksheet and implementation.

Keywords: ATAP, STEM Learning, Computational Thinking Skill

Introduction

Our education today was not quite suitable to prepare students have high-skill related to global society. Many teachers still not have various strategies to involve students in future-ready learning. As a teacher who has responsibilities to teach millennial students, we know that it is not easy to make an interesting lesson suitable for global pretension. Our learning still has focused to achieve base competences in the curriculum for cognitive exam. Students are not very often to develop step by step solutions of real-life problem in the learning process. In fact, many students are not used to critical thinking because they are very often learning just for understanding phenomena or concepts without application the concept in order to solve the problem. Meanwhile finding solutions regardless of the problem is a skill to prepare students for challenges and job that possibly do not exist today.

One of the future-ready competences is Computational Thinking Skills (CTS). Computational Thinking is nowadays the fifth of twenty-first century's skills for every individual's needed. Two main approaches to enhance CTS are computerize activities mainly programming exercise and unplug activities which is no use digital device. Each approach has different advantages of implementation. An advantage of computerize activities is improving computer technology literacy. We know that more than hundred thousand new job related to computer has been opening. Just individuals who has good-skills will fill the job vacancy today and in the future.

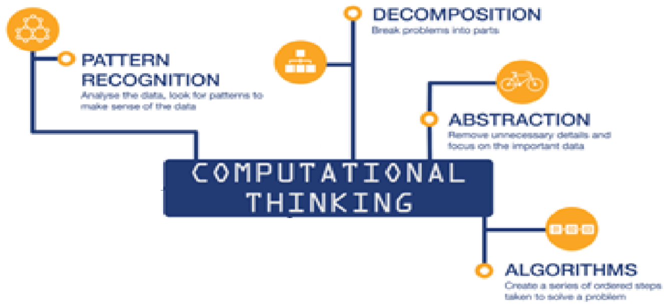
However, based on the results of observations, the students' CTS still need to be developed. When the first time I implemented STEM learning Using Arduino, most students were still depend on teacher's explanation for completing the Arduino project. Students are less trained in making designs and problem solving steps through the project. In order to minimalize this problem, we need an approach to improve student's CTS.

Computational Thinking involves solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science (Wing, 2006). Computational thinking is not only about programming but how writing a program could solving real life problem, what the best way to solve the problem and breaking down the complex problem to particular problem. Next Generation Science Standards (2013) (Psycharis & Kotzampasaki, 2019) suggest that CT "is a core scientific practice and due to the increased presence of computation in mathematics and scientific contexts, a new urgency has come to the challenge of defining computational thinking and providing a theoretical grounding for what form it should take in Science and Mathematics".

The Australian Curriculum Assessment and Reporting Authority (ACARA, 2020) defines:

> Computational thinking is defined as "a problem-solving method that involves a variety of techniques and strategies which may include organizing data logically, breaking a problem into parts, designing and using algorithms and models"

Adopted from Australian Curriculum Assessment and Reporting Authority (ACARA, 2020), Computational Thinking is divided into several sections as shown in the picture 1.



Picture 1. Computational Thinking

In line with the description of ACARA, Hidayat (2019) state that:

1. Pattern Recognition, ability to see the similarities or differences in patterns, trends and regularities in the data that further is used for predictions and data presentation. The same solution can used to solve the problem, which has similarities in patterns.
2. Abstraction, finding characteristic of problem, determine what details we need and what we can ignore to solve the problem.
3. Decomposition, breaking down a complex problem or system into smaller, more manageable parts. The solution begin for every smaller part toward more complex problem.
4. Algorithm Design, develop the step-by-step solution to the problem.

One alternative of the learning approaches that can be supposed to enhance Computational Thinking Skills (CTS) is STEM learning. The research of Psycharis and Kotzampasaki (2019) concludes that STEM Learning has positive influence on the dimension of Computational Thinking. STEM education is a strategy to improve technology literacy as an important skill in this twenty-first century era. Akgun (2013) describe that technological literacy (TL) is one of the most important qualifications for a 21st-century person to acquire (ETS, 2003), and STEM education is important for the acquisition of this qualification. Technological literacy is, “the ability to responsibly use appropriate technology to: Communicate, solve problems, access, manage, integrate, evaluate, design and create information to improve learning in all subject areas, and acquire lifelong knowledge and skills in the 21st century” (Technology Literacy Assessment Project, 2009, p. 1).

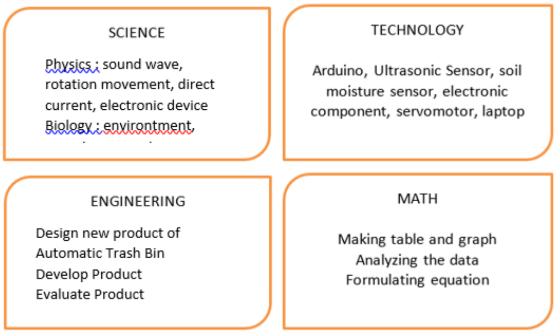
In addition, through STEM learning, students practice to implement engineering design process (EDP) which is an important curriculum in this century. Morgan (2013) mentioned that “The design process is a systematic approach followed when developing a solution for a problem with a well-defined outcome”. There are many variations in practice today, but most of them include the same basic steps. Following a well-structured design process is important because it provides the structure needed to formulate the best solution possible, and the act of following a design process builds problem-solving skills and logic”.

Morgan in Akgun (2013) represented utilizing a seven-step process of Engineering Design process (EDP). First step is identify problem and constraint. This process aim to capture student’s interest in the design problem, motivate and involve students to identify problem related to the human element. The important process in the first step is to find out what the students already know to kick off a project and constraints. The second step is research. This process is a vital activities in the lesson. The students do their research related to find out solution for the problem. Based on the result of the research, next step students generate ideas and analyse ideas about the product in order to solve the problem. They can use math, science and technology concept that are used in their ideas to make a design. After they have ideas of the design, they build the project or product. Students learn better when they have opportunities to apply the concept in a context of real world. The next step is test and refine. Students compare the result of the test and their prediction, they analyse the results based on the problem criteria and objective. They refine their design solution, and used critically thinking to rebuild the project. The last step of EDP is communicate. Students communicate their product or project and also have to describe the weakness and strengths of their project.

There are some benefits of using engineering design in the classroom. Engineering requires high order thinking skills, build 21st century skills, such as problem solving and creativity, cultivates skills required for successful collaboration and teamwork and develops a stronger interest in science, technology, and mathematics concepts, provides an environment where metacognition and journaling are of great importance and the purpose of these activities are better understood and appreciated (Akgun, 2013). One research about the impact of implementation STEM has been conducted by Psycharis and Kotzampasaki (2019). They were designed and implemented STEM Inquiry using computational tools such as Arduino and RGB LED in Greek public school 5th - 6th grade. The findings indicate a positive influence of integrated STEM in the teaching sequence in order to enhance students’ confidence with computational experiments.

Method

The brief line of STEM components in this learning as shown as Picture 2. Science mastery in this learning had been have by students before the implementation.



Picture 2. ATAP STEM Learning Briefline

Students were put into four-member teams. Every group were given some electronic components including some sensors and Arduino UNO. Students could use all of the components or just use some components and ignore some others. They had to complete a Trash Bin Project to solve the rubbish problem around School.

In the previous lesson (before the implementation of ATAP), students had been learnt how to use Arduino UNO in the classroom. The teacher gave worksheets to each group with step by step instruction. Students in a group worked together in completing the worksheet and finally they make a product.

In the first lesson of ATAP implementation, students got some modules about basic circuit to use Arduino UNO and some sensors. But not all of source code in the module is true source code to program Arduino UNO. There are some mistake of source code, which students have to find and fix. Students in a group made a discussion about problems around the school, which is important to be solved. In the classroom, students had to break down the problem into some smaller problems and think about the solution for each smaller problem. They also make a design, choose the components, and write the idea of product that could solve the problem.

The second lesson of implementation was conducted outside the classroom but students could discuss with teachers and make a research in order to complete the product (Automatic Trash Bin) still. In this lesson, students got 3 weeks to complete their project. They can learn about basic programming Arduino electric component circuit and sensor by themselves using a module. After students build the product, students tested, analysed and refine product before the class meeting. In the class meeting as third lesson, students communicate and present their product in front of other students and five teachers as observer and evaluator.

The design of STEM Learning Using Arduino to enhance Computational Thinking Skills (CTS) as shown in Table 1.

Table 1. Design of STEM Learning Using ATAP with CTS Indicator

STEM Learning	The Implementation of Automatic Trash Bin Arduino Project (ATAP)	CTS	CTS Indicator
Identify Problem and Constraint	Students have to identify what are the problem around them and what is the product that they can made in order to solve the problem.	Decomposition	- Identify the problem - Break down the problem into smaller problem) - Break down the big project into smaller project
Research	Students explore about the problem and solution in STEM perspective. Students also explore about using Arduino through module (including various tutorials) independently and determine which tutorials were needed to design and build a product.	Abstraction	- Identifying the objects characteristics through direct observation - Generalizing to determine some objects in completing the project and ignoring irrelevant object (keep the other object in the box) - Making Connection between process or concept to form a new understanding. For example about pin number concept in Arduino.
		Pattern Recognition	- look for similarities among and within problem, fix the wrong source code based

			on the patterns and write their own source code.
Ideate and Analyse Ideate	Students ideate and analyse ideate in order to make a design of the product and explain how is the functionality, what the components, the advantages and limitation. And students explain how the product can solve the problem in STEM perspective	Algorithm Design	- explain a step by step procedure to make a project - design the Automatic Trash Bin Arduino Project
Build	Students make a product based on their design using Arduino and appropriate components (sensor)	Algorithm Design	- build their own program (source code) to complete the project - build their product (Automatic Trash Bin) by their step by step procedure
Test and Refine	Students do some test, redesign and revise the product	4 Skills	- identify the wrong function of product (bug) - redesign and revise the product by fixing the bug
Communicate and Reflect	Students did the presentation and communicate to the teacher and other students in front of classroom		

To figure out the enhancement of students' Computational Thinking Skills (CTS), students' writing answers in a worksheet was analysed based on portfolio assessment rubric. How quality of students answer, how they finished the worksheet and their product were analysed in order to record their CTS performance. This portfolio assessment is a grading rubric to indicate different levels of achievement for each dimension of CT performance or a checklist to indicate whether a certain criteria is met. Rubric of portfolio assessment and its criteria as shown as Table 2.

Table 2. CTS Indicator and Rubric of ATAP Portfolio Assessment

CTS	**CTS Indicator**	**Rubric of ATAP Portfolio Assessment (Score)**		
		1	**2**	**3**
Decomposition	- Identify the problem - Break down the problem into smaller problem) - Break down the big project into smaller project	- Just write 1 problem as a big problem	- Write 1 big problem - Write 1 smaller problem as part of manageable problem	- Write 1 big problem - Write 2 or more smaller problems as part of manageable problem
Abstraction	- Identifying the objects characteristics through direct observation - Generalizing to determine some objects in completing the project and ignoring irrelevant object (keep the other object in the box) - Making Connection between process or concept to form a new understanding. For example about pin number concept in Arduino.	- Determine objects but not all object related to feature in their project - Ignore (Keep in the box) other object which is not used in their product	- Determine objects /components related to feature in their project - Ignore (Keep in the box) other object which is not used in their product - Explain the functionality of all object that they had been Chosen	- Determine objects / components related to feature in their project - Ignore (Keep in the box) other object which is not used in their product - Explain the functionality of all object that they had been Chosen - Make a correct picture of circuit consist of Arduino, component and connection the component into pin number

Pattern Recognition	- Look for similarities among and within problem, fix the wrong source code based on the patterns and write their own source code.	Fix 1 wrong source code and write the true source codes	Fix 2 or more wrong source code and write the true source codes	- Fix 2 or more wrong source code and write the true source codes - Write some new source code related to the feature of the project
Algorithm Design	- Explain a step by step procedure to make a project - Make a design / diagram the product (Automatic Trash Bin Arduino Project) - build their product (Automatic Trash Bin) by their step by step procedur	- Make the design diagram / flowchart how to make the product (Automatic Trash Bin Arduino Project) based on the design from internet, etc - Build their product (Automatic Trash Bin) refers to their design	- Make the design / diagram / flowchart how to make the product (Automatic Trash Bin Arduino Project) - Build their product (Automatic Trash Bin) refers to their design.	- Make their original design / diagram / flowchart how to make the product (Automatic Trash Bin Arduino Project) - Write step by step procedure to make a project/product including its features - Build their product (Automatic Trash Bin) refers to their design

During the lessons students were also observed by five teachers (as observer). Some teachers (math, biology, physics, chemistry and IT) did a collaboration in this research to be observer. They used portfolio assessment of product to give the students feedback and evaluation. The teachers as observer was involved in the first lesson when students identify the problem, research, ideate and analyse ideate and in third lesson when students communicate the product.

To find out the effectivity of learning process, before and after implementation, students were given pre-test and post-test about the concept mastery with the same instrument. Based on the score of pre-test post-test, the effectivity of learning determine by normalized gain score Hake (2008). Students who involved in this study are grade 12th of SMA Labschool UPI 2019/2020 school year.

Results and Discussion

The implementation of the lesson was conducted by blended learning. In carrying out independent assignments, students and teachers continue to discuss project completion through WhatsApp groups. Students have a longer time to finish the project, doing their own research, learn how to use Arduino by themselves, and also collect all of the resources to complete the project. In this implementation, students got various kind of Automatic Trash Bin that they want to complete. They found several problems around the school and had to solve one problem with the product using Arduino. They can determine what components, designs, and functions to solve the problems they have chosen.

Based on portfolio assessment of worksheets, students' CTS can be seen in Table 4.

Table 3.Students' CTS Profile

CTS	Finding	Total Score	Percentage (score/max score)
Decomposition	All groups demonstrated Decomposition Skill based on their report of the project. Students describe about the	15	83%

	problem which was solved by the product. They described each function of the product in order to solve the problem		
Abstraction	- All groups demonstrated abstraction skill based on their report and their component to build the product. Students determined component/object in completing their product, assemble the component based on the picture of fritzing (circuit).	- 16	- 89%
Pattern Recognition	All groups demonstrated pattern recognition based on their code. Students were able to write their own code after recognize the similarities or pattern. They wrote code for their program specification and limitation.	16	89%
Algorithm Design	There were 6 group draw the design of Automatic Trash Bin. Only 3 groups could write the procedure how to make the product, the design and the procedure. 2 groups wrote the design and procedure which was taken from the internet, One group was not able to make a design of product.	10	59%

Based on the description in the table above, this study indicate positive influence to enhance students' Computational Thinking Skills especially on abstraction, pattern recognition and decomposition. During the implementation, students show their CT skills. Students did some discussion about the components and determine what components to complete the product, they make their own decisions. They did some creations by changing the code for basic circuits and completing products according to their designs and knowledge. Here are some various product as applications of their knowledge and skills in order to solve the problem.

From 6 groups of students, 4 groups have creativity to build a product which has more than 1 feature. Every group could complete the project by themselves. Only 2 groups did not yet show creativity in completing the project. This 2 groups (Group 3th and Group 6th from table 6) also wrote the step by step solution which taken from internet without modification or added some creation. They did not show the algorithm design process in their report. We could conclude that algorithm design skill were considered need more time to practice. The picture below are some example products and activities when students communicate their product.

Picture 3. Some Products and Activities

The learning effectivity as students' cognitive outcomes based on normalized gain score could be seen in Table 6. The normalized gain score is 0,66 in average category. This indicates that STEM Learning Using ATAP is worthy to implement. Even though the teacher was not teach directly to students, students can learn more knowledge and skills by themselves using module, worksheet and task to complete the project.

Table 4. Normalised gain Score

	Average Score	Deviation Standard (S)
Pretest	4,20	1,45
Postest	21,23	3,16
Normalized Gain	0,66	0,11
Criteria	Average	

Furthermore, the finding of this study conclude that STEM learning using Automatic Trash Bin Arduino Project (ATAP) has good impact to enhance students' Computational Thinking Skills especially on abstraction, pattern recognition and decomposition but on algorithm design still need more time to practise. In the other hand, the learning effectivity STEM learning using Automatic Trash Bin Arduino Project (ATAP) in average category.

Conclusion

Based on the students' observation results, products, and worksheets, STEM Learning using Automatic Trash Bin Arduino Project (ATAP) has good impact to enhance students' Computational Thinking Skills (CTS) especially on abstraction, pattern recognition and decomposition. Students demonstrated abstraction and pattern recognition skills as the high enhancement. On the other hand, students need more time to enhance algorithm design skills as the lowest enhancement. Students demonstrated decomposition and algorithm design when they have their free learning to complete the project. In addition, students show creativity in their product and have new knowledge as result of their own research. Furthermore, the results showed that learning effectivity as students' cognitive outcomes with normalized gain <g> valued at 0.66 with average category. These findings indicated that STEM Learning using ATAP is worth considering in learning physics. Although there are many things need to be improved such as learning material (worksheet and module) and teacher instruction.

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