Research Article

Construction of the STEAM Learning Model with a Design Thinking Approach on Renewable Energy Materials

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Abstract.
The industrial revolution 4.0 accelerates the need for resources with contextual skills that are relevant to technological advances. Renewable energy is a global issue that needs to be followed up as a concern in education. The concept of STEAM learning is seen as a learning innovation that accommodates the skills needed in the era of the industrial revolution 4.0. In addition, through a design thinking approach, students are facilitated to realize creativity or ideas in solving problems around them. This study aims to reconstruct the STEAM learning model with a combination of design thinking approaches in renewable energy learning materials. This study uses a descriptive qualitative approach with data sources from the literature. The analytical tool used is the Miles and Huberman interactive model data analysis. The expectation from this research is the formulation of a combination framework between the STEAM learning model and design thinking that can be applied to learning renewable energy materials.

Keywords: Design Thinking, Renewable Energy, STEAM

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1. INTRODUCTION

The emergence of the STEAM (Science, Technology, Engineering, Art, Mathematics) learning concept is one of the alternative learning innovations that involve all aspects needed for 21st century skills. The new focus in the world of education is to require the application of these aspects in learning activities. This will allow students to connect with STEAM in their learning practice [1], [2]. STEAM is an interdisciplinary learning that incorporates art and design into STEM that aims to improve the critical thinking skills and creativity of learners [3]. STEAM learning adaptation is considered important for prospective educators to improve the quality of Indonesian human resources in order to be able to compete in the world arena, especially related to the ability and skills to produce science and technology-based products [4].

Educators face a challenge to create an interesting and interactive learning innovation. Student interest can be judged by students' interest and motivation to learn during learning. Taufiq et al stated that students who have an interest and motivation for learning will naturally feel happy to follow the learning, so that students can more easily understand the learning material[5].

The STEAM (science, technology, engineering, arts, and mathematics) learning method has become very popular today due to its ability to facilitate students to understand lessons and solve problems critically. In addition, students also become able to analyze data and innovate in solving existing problems. The STEAM method is believed to be able to increase the motivation of students to actively participate in the effective teaching and learning process in the classroom [6]. In learning with the STEAM method, teachers deliver lessons through experiments to grow students' ability to think logically, mathematically, practically, and scientifically in understanding the lesson. The STEAM method is used in lessons because the learning motivation of learners can be increased by making curiosity about the relationship between the lessons learners get at school and the real conditions in everyday life [7], [8]. Thus, the need for innovation in the use of Science Kit media that facilitates the STEAM learning model as a means of teaching and learning activities. Although the STEAM learning method is very popular today, the STEAM method is still relatively new in Indonesia and not many schools have adopted the STEAM learning model.

2. METHOD

In an effort to examine the problem, the authors used a data analysis model referring to the descriptive analysis approach developed by Miles and Huberman. Descriptive analysis consists of three main components of the analysis that are carried out simultaneously since or in conjunction with the data collection process [9]. These components are data reduction, data presentation, and conclusion as shown in the following Figure 1.

Descriptive analysis has several stages ranging from data collection to affirmation of conclusions or verification of argumentation (analysis results). Secondary data collection is carried out through the instruments previously described. Furthermore, the data is deciphered (reduction) to find influences or relationships between variables. The presentation of data is carried out in conjunction with the decomposition of data to facilitate analysis. So that the next from the results of presenting data and deciphering the conclusions of the analysis are obtained. The last step is to relate it to the theory

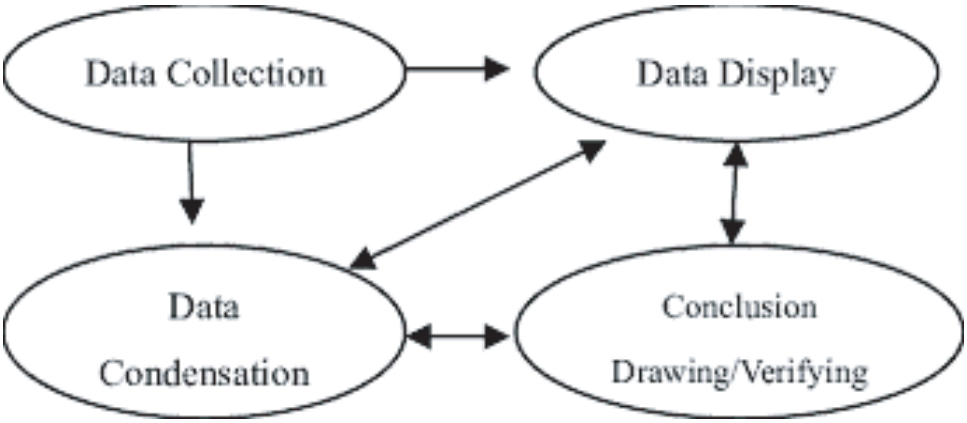

Figure 1: Interactive Model Data Analysis.

or verification of the findings of the results of the analysis that has been carried out before.

3. RESULTS AND DISCUSSION

Before the STEAM-based learning model, there was a STEM-based learning model which was a learning innovation that focused on science, technology, engineering, and mathematics. This model was a breakthrough in America to encourage innovation because science and technology were the main keys to progress at the time. Later, the word art was first coined as STEAM by Georgette Yakman at the Rhode Island School of Design because according to him, science and technology can be interpreted with engineering and art and all of them contain elements of mathematics (Riley, no date). Furthermore, STEAM-based learning is then interpreted with a learning approach that helps the realization of experiental learning and the ability to solve problems based on the assumption that science, technology, engineering, art, and mathematics are interconnected. This is also in line with Maeda (2013) who added art to STEM to STEAM because he believes that in the 21st century, it is design and art that will change the economy as science and technology have acted out in previous centuries. Therefore, the STEAM approach is a great opportunity to prepare a generation that is ready for these conditions.

Referring to Kamienski and Radziwill (2018), STEAM can be done by: (1) identifying key activities; (2) identify sub-activities; (3) define the specific advantages that can be achieved; (4) choosing a matrix/developing data retrieval; (5) explore the social aspects involved; (6) exploring individual expediency[10]. According to Uswah (2019), STEAM components are detailed more operationally, consisting of: (1) problem solving

through innovation and design; (2) the relationship between assessments, study plans and learning standards; (3) the combination of more than one subject in STEAM and its usefulness in art; (4) a collaborative and process-based learning environment; and (5) focus on things that happen in life [11].

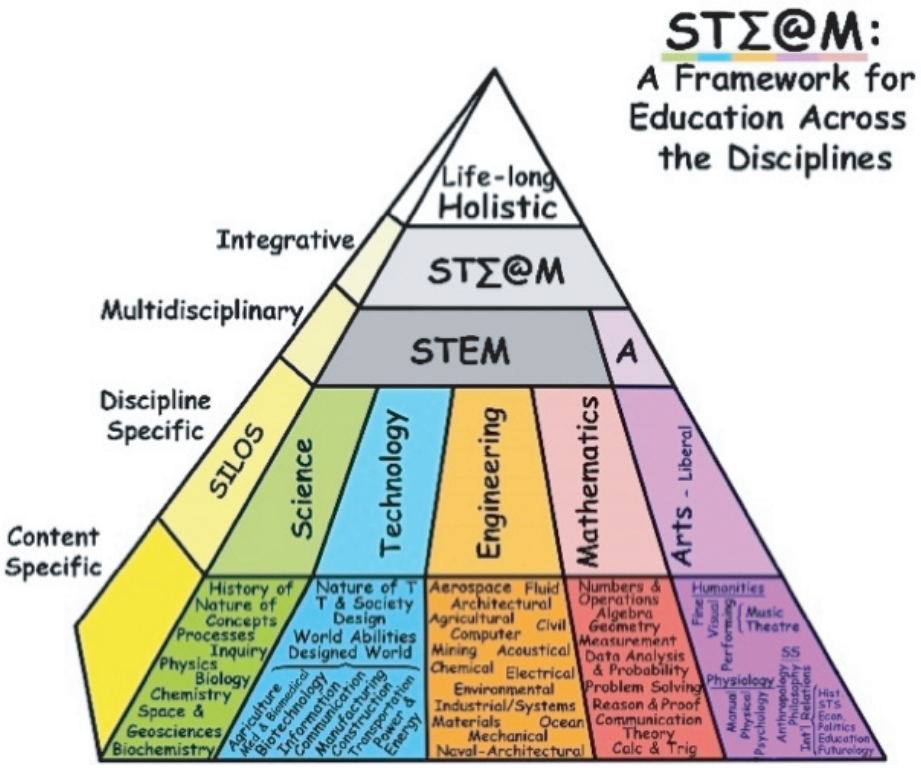

Figure 2: Multidisciplinary Learning Framework.

Thibaut et al (2018) concluded that the STEAM framework consists of 5 things, namely: (1) integrating STEAM content; (2) problem-based learning; (3) inquiry-based learning; (4) design-based learning; and (5) cooperative learning. In STEAM learning, there is no known isolation of subjects. Science and technology can be interpreted through art and engineering, and also includes mathematics. Each of the fields of science explains each other one and the other [12]. A learning problem is viewed comprehensively across subjects in the curriculum [13]. It should also be remembered by educators, the STEAM approach is basically inquiry-based learning so that assessment must still focus on the achievement of knowledge or skills. To find out the achievement of integrating art in STEM, where and to what extent should the meaningfulness of the project being carried out should be the main one [14].

The spirit brought to the STEAM approach is in line with the implementation of thematic learning in elementary [15]. Thematic learning began during the implementation of Kuriulum 2013, especially for grade 1, 2, and 3 elementary school students.

Thematic learning is student-centered learning, integrating several subjects, providing direct experience to students, being flexible, and giving learners the opportunity to develop according to their aptitudes [16]. Thus, it is hoped that learning can further stimulate students' ability to face the challenges of the 21st century which requires the possession of 4C competencies: creative, critical thinking, communicative, and collaboration[17]. From this description, it can be concluded that STEAM-based learning is in line with thematic learning carried out, especially in elementary schools after the enactment of the 2013 Curriculum [17]. In thematic learning, learning is not based on subjects, but rather by being given one theme which is then reviewed from a number of subjects. Thus, it is expected to provide a more meaningful learning experience to students. This is in line with the steam-based learning spirit. Therefore, the ability and ability of teachers at the elementary school level to integrate STEAM into their learning is expected to further optimize the learning experience of students.

3.1. Stages of Design Thinking in Structuring a STEAM Project

Design thinking is a thought process to solve complex problems with simple solutions. Design thinking is a stage of thinking that involves reason (Head) feelings (Heart) and skills (Hand) so that the result of the mind is a combination of logic, imagination, intuition, and art. Design thinking is a new mindset approach that aims to train one's creativity in solving contextual problems and oriented to the needs of its users with certain stages. In short, design thinking is a mindset methodology for designing innovative products that are not only effective in terms of function but also prioritize aesthetics.

The stages of the thinking process in design thinking according to (Plattner, 2018) in his book "An Introduction to Design Thinking Process Guide" describes there are 5 stages in design thinking that a person / group must go through to be able to produce an innovative product that has been adapted to the needs of its users. Of course, all stages in design thinking must be passed gradually, systematically and thoroughly. The five stages are: (1) empathy, (2) define, (3) ideate, (4) prototype, and (5) test [18]. The application of the stages of design thinking in compiling a STEAM project, can be seen in table 1 below.

The Empathy stage is the first step of design thinking. (Ambrose, 2010) mentions that empathy is the spirit of the design of one's thought process. Empathy means the will and ability to understand the feelings of the other person why and how he does things. Furthermore, Supriyadi, (2019) said empathy is a way of understanding a person's physical, psychic, and emotional needs in living his life, so that with empathy we can

Table 1: Stages of Design Thinking in Compiling STEAM Projects Based on Science Subjects in Elementary Schools.

No	Stages	Activity Description
1.	*Empathy*	The teacher invites students to observe daily activities. Students are guided by the teacher to observe the need for electrical energy in everyday life. Learners conduct interviews with parents how much electricity costs in a month. Students record complaints or wishes of parents regarding problems encountered in meeting the needs of electrical energy. Students make empathy maps of the problems faced.
2.	*Define*	Students convey the subject matter based on the results of observations and interviews. Teachers guide students to find the cause of the problem why electrical energy is scarce or expensive. The teacher holds the learner's opinion regarding the solution needed to solve the problem
3.	*Idea*	Teachers and learners determine the technology that can be used to solve these problems by using several relevant learning media series. The teacher relates the selected technology to the basic competencies / subject matter that are appropriate, namely: Energy Changes Renewable energy or alternative energy Teachers and learners inventory the resources, tools and materials needed The teacher demonstrates the learning medium as well as provides guidance on how to operate. Teachers and learners arrange steps and schedules of activities
4.	*Prototipe*	Students in groups arrange learning media according to predetermined stages. Teachers monitor the activeness of students during the preparation of learning media. Teachers guide and provide assistance to students to be able to complete projects according to predetermined stages and times Learners complete projects to experiment
5.	*Test*	Teachers and learners test the effectiveness of the operation of learning media. Teachers provide input and improvements during the trial process. Learners correct project deficiencies Teachers guide learners to compile reports

find something meaningful to change his life [19]. Through empathy we can find out in detail the problems faced by others, so that the resulting product becomes an effective solution to improve the quality of life. Empathy will dismantle what others actually need from their own point of view, not from personal assumptions. This thought process based on empathy is what will produce the right product because it really suits the needs of its users.

The define stage is the limitation of the problem, that is, the process of determining which problem is considered the most important to be immediately followed up to the next stage. This stage is also interpreted as a phase to determine the characteristics of needs. During the define phase, product designers are asked to inventory what things

are needed by potential users in order to avoid difficulties or problems encountered. The define stage is an important step in determining the achievement target. When the goal has been set, then we just have to focus on thinking about how to get to the goal. Razzouk (2012) explains that the define stage is the phase of finding the core point of view of the problem [20]. This stage is the fulcrum to determine the focus of the problem while analyzing its needs. The way to determine the point of view (Point of View) at the define stage is to analyze the information of the findings at the empathy stage. Analysis can be helped by answering essential questions that lead to the root of the problem.

The ideate stage is the phase of contemplation to find a solution. The idea phase is interpreted as the birth of creative ideas that can arise from the process of imagination or the refinement of pre-existing ideas. The stages of collecting creative ideas generally begin with the relationship between logic and creativity. how to come up with an idea at the ideate stage? One of them is through brainstroming. Brainstrorming is a technique to accommodate various inputs from the results of other people's thoughts in solving problems. Each person or member is given the same opportunity to express opinions openly and freely from the intervention of others. The ideas that arise are discussed to find out the advantages or lack thereof. The ideas presented at least contain concepts and procedures that are ready to be developed into a prototype.

This stage of the prototype is the phase of visualizing ideas into realizations. Prototype means an initial form that describes the design, concept, and work system of a product. Prototypes are interpreted as the real embodiment of an idea before it is made on an actual scale or mass-produced. The prototype stage in design thinking is the activity of designing, compiling, and modeling a product that is ready to be tested for feasibility. This stage requires hard work because it must be able to realize the concepts and procedures that have been prepared in the previous stage so that they can be seen, palpable, and applied in their actual form. In addition, this phase requires a high level of patience and consistency because it has to go through a process of trial and error repeatedly. The steps taken to complete the prototype phase include the division of tasks. There are those in charge of collecting tools and materials, forming prototype parts / components according to composition and size, assembling materials according to design (shape), designing work systems (usage procedures), to record every development.

The Test stage is a feasibility test or readability or acceptance of a product prototype that will later be developed into a final product or made in large quantities. The feasibility

and effectiveness test aims to find out the extent to which the prototype that has been made is able to solve problems and is in accordance with the needs of its users.

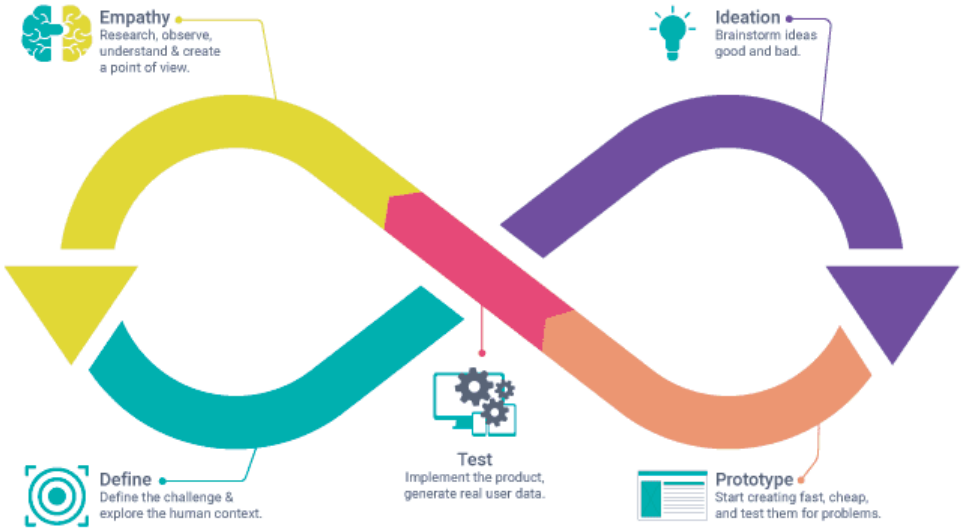

Figure 3: Design Thinking Process.

3.2. STEAM City Learning Media

STEAM City is a learning medium in the form of a miniature game series applying science, technology, engineering, art and mathematics in a miniature city that can be disassembled by students. Steam City games aim to hone critical thinking, problem solving, innovative, logic, and of course the most important point is creativity. Learning in STEAM City will initially apply some of the material of force, motion and most importantly the subject matter of energy. The matter of force, motion and energy is a continuous matter where the presence of force will cause motion and motion can be converted into energy. In STEAM City, arduino is applied as an IoT (internet of things) based controller. In the complete package of the game series, there are several sensors such as light sensors, motion sensors, and electric current sensors. Other sensors can also be combined. This sensor is the input or input to the Arduino system and can later be intervened automatically and can also be operated via a smartphone.

In this game series, students will be introduced to the materials contained in a battery, units in electricity and the mechanism of change from chemical energy to electricity then to movement and light. In this material, series and parallel frame materials can also be developed as well as electric currents from various energy sources in the wind turbine series, solar panel series and Micohydro series. Of course, in each measurement will be assisted by using sensors and will be able to be displayed via a smartphone. In

operations such as on / off, moving the propeller, turning on the lights, moving the crane is done through a smartphone or pressing the touch screen contained in the empire state building. The application of STEAM City to the science subject of renewable energy materials can be described according to table 2 below.

Table 2: Description of STEAM Product Design Based on Science Subjects in Elementary Schools.

No	Aspects	Description
1.	Product Name	STEAM City *series wind turbine, solar panel*, *Microhydro* and *Smart Home* series
2.	Class / Semester	4 / Semester 1
3.	Subject Bases	IPA
4.	The interrelationship of concepts between materials	Force Matter, Energy Change Matter and Alternative Energy Matter
5.	Purpose	Stringing the STEAM City series as a miniature solution to the problem of scarcity of electrical energy
6.	Product Description	The *wind turbine* series is used to demonstrate Wind power plants, the *solar panel* series is used to demonstrate solar power plants, the *Microhydro* series is used to demonstrate hydroelectric power plants and the *Smart Home* series is used as a control center and miniature houses.
7.	Tools and Materials	STEAM City *series wind turbine, solar panel*, *Microhydro* and *Smart Home series,* Scissors, Insulation and Glue
8.	Product prototype drawings / designs	
9.	Ways of manufacture	Prepare tools and materials Arrange the components of each STEAM City series according to the guidelines Glue or bolt components according to the needs of each series Series STEAM City according to the instructions Connect the wiring according to the label listed Turn on Smart Home via the on/off button on the left Do the treatment according to the instructions in the guidebook

Renewable energy materials (water energy with the working principle of hydropower) can be applied by making a waterwheel on which a hose has been applied to pour water from the water pump. In this game, students try to observe the power of water to move

the waterwheel. Students influence the force of gravity and water discharge will affect the frictional force of water on the surface of the pinwheel, so that the pinwheel moves. Learners can observe the magnitude of the power of the electric current generated by water. The calculation will be assisted by sensors and will be displayed through a screen on the empire state building series or can also be monitored via a smartphone.

Renewable energy materials (wind energy with the principle of PLTB) can also be applied as the principle in hydropower plants but waterwheels are replaced by using propellers, and the wind source comes from the blowing of students. Learners can blow the propeller slowly or powerfully to prove that the force of the wind is capable of moving the propeller. The movement comes from wind friction on the surface of the propeller blades which gives rise to motion from the wind energy being blown.

Light energy matter or those sourced from solar alternative energy can be done through the application of solar panels. Learners will do a practicum by placing the game series in the hot sun or simply by highlighting it with a flashlight. Learners will observe the electrical power generated through indicators displayed on the empire state building screen or through a smartphone. Students can also add a series of solar panels and see changes in the energy produced, the electrical energy produced can be used to supply energy to the battery and also other series of games.

Matter changes in energy, chemical energy, electrical force and circular motion can be applied through battery schemes as a source of chemical energy that is converted into electrical energy which can also transform into various forms such as motion and light.

STEAM City is basically a game of combining, assembling and combining various series into a city according to the imagination of students. Each series can later be paired with other series through a puzzle-shaped base. The designs of several series are in the form of houses or buildings with indicator screens and lights, in the form of wind turbines, waterwheels, tower cranes, and others. The basic series that must be owned is the smart home series as an Arduino-based controller. The smart home series serves as a sensor processing center and command control center. STEAM City product outputs include miniature games, arduino controller program, smartphone application 'Blynk IoT' which can be downloaded via *playstore, website,* videos and guidebooks. In the future, STEAM City can be developed into a learning medium in introducing more complex physics materials, programming, IoT work systems and Robotics. Examples of practical steps for learning by applying STEAM City in accordance with the STEAM learning model and design thinking approach are presented in table 3 below.

Table 3: Learning Activity Steps.

Learning Phase	Learning Activities (Student-centered)
Introduction	Teachers and learnerssing the song "Saving Electricity", Development of the lyrics of the song "Planting Corn" *"Ayo kawan, kita bersama Menghemat listrik di rumah kita Matikan lampu disiang hari Pakailah lampu hemat energi Buka, buka, buka jendela Cahaya masuk, udara segar Mati, mati, matikan listrik Matikan listrik jika selesai Jika selesai mengisi baterai lepaskan alat dari stop kontak Gunakan alat berdaya kecil Lepaskan kabel jika selesai Hemat, hemat, hematlah listrik Menghemat listrik hemat energi Hemat, hemat, hematlah listrik Menghemat listrik menghemat uang"* The teacher conducts a question and answer activity: "Did you guys turn off the lights when it was getting bright?" "Does your house often have power outages?" The teacher holds the students' answers Teachers and learners carry out brainstorming activities: "Why should we save electricity?" "How to make or produce electricity?" The teacher told about the figure of the invention of electricity and also showed power plants in Indonesia. Teachers deliver learning objectives *"This time we will learn about energy. We will study the various kinds of alternative energy and how the process of producing electricity from renewable energy sources. The goal after you understand it, you will save more energy and be able to apply it in everyday life.* The teacher conveys the agenda of activities that will be carried out during the learning process: *"During the learning activities, we will learn to solve problems related to energy in everyday life.*
Stages of Project Based Learning	
Designing planning	Classes are conditioned into small groups The teacher takes students around the school to see tools that use electrical energy or can be replaced with home assignments Teachers guide learners to conduct interviews with parents regarding electricity use and monthly electricity costs The teacher invites the students back to the classroom / school Each group finds the root cause by compiling a list of questions about: Why does that problem happen? What should be done so that the problem can be resolved? What does a home or city need to solve the problem? How do I make it happen? Each group determines a solution that could alternatfi renewable energy sources
Building a Schedule	The discussion group agrees on the number of meetings needed and the targets / progress to be achieved at each meeting The teacher guides each group to schedule the project from planning to product improvement **Meeting Activities Date Realization Constraints 1 Planning the product 2 Designing products 3 Preparing tools and materials 4 Product Manufacturing 5 Product Presentation 6 Trial 7 Product Improvements 8 Reflection and Evaluation**
Monitoring the activeness and development of the project	Each group reports the progress of project achievement at each meeting The teacher asks about the progress achieved and the obstacles faced by each group Teachers guide and provide assistance if there is a group that has not been able to achieve the target The teacher records the progress of the project at each meeting Each group ensures that the product prototype must be completed according to a predetermined schedule
Testing the results	At a predetermined time, each group brought a prototype of the product to be presented Group presentations include: Necessary materials and tools Product manufacturing process Parties who play a role in the completion of the product The advantages possessed by the products that have been made Teachers guide the process of testing the effectiveness of product prototypes Each group conducted product prototype trials while the other group observed and recorded the results obtained (its advantages and disadvantages) Presentation of the observations of each group
Evaluation of the learning experience	Teachers provide input for improvement or refinement of the prototype Each group fixes the weaknesses or shortcomings of the prototype that has been tested The group designed the revised final prototype
Cover	Teachers and learners to reflect on learning Teachers provide reinforcement Teachers deliver follow-ups/assignments

4. CONCLUSION

The STEAM learning model is very relevant to the skills needs of the 21st century and the design thinking approach strengthens a more contextual learning model in providing practical understanding through solving the problems in daily activities. The construction of a STEAM learning model based on Design Thinking on renewable energy materials requires learning media that accommodates each stage of thinking in solving a problem, which includes (1) empathy; (2) define; (3) ideate; (4) prototype; (5) test. Through STEAM City learning media, students are expected to be able to understand renewable energy materials applicatively in a miniature city with a continuous scope of material between force, motion, and energy. STEAM City learning media can continue to be developed in accordance with the creativity of students and educators. Educators serve as facilitators, promoters and evaluators on learning models using STEAM City learning media. It is hoped that the construction of the STEAM learning model with the Design Thinking approach can be developed and applied to shape the skills of students in accordance with the times.

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