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Design of Physics Science for Early Childhood: Theoretical and Conceptual Framework of STEAM

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Abstract

Good problem-solving will occur if children have good thinking skills and scientific knowledge. This scientific knowledge and thinking skills can be built through learning that integrates the concepts of literacy and STEAM. Physics is one form of science that can be used to develop the concepts of literacy and STEAM. This article aims to introduce activity designs that carry the concepts of literacy and STEAM, which can help early childhood students integrate science, technology, engineering, art, and mathematics to achieve certain targets. A more detailed concept of content that carries the concepts of literacy and STEAM is developed as a recommendation to education implementers. This concept design is based on the scene setting for early childhood. This study applies the 'most appropriate framework synthesis' approach, supported by interviews, in-depth observations, and literature reviews, to strengthen the conceptual framework in this study. The results of this study are a conceptual framework that refers to STEAM education but is more focused on the subject of physics. With a clear and completely structured conceptual framework, it is hoped that learning activities with the STEAM approach can run optimally and help stimulate cognitive, language, psychomotor, and social-emotional understanding in early childhood through the five STEAM disciplines.

Keywords

Conceptual Framework; Early Childhood Education; STEAM; Physics Education

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1. INTRODUCTION

The concept of 21st-century skills is increasingly widespread in educational discourse globally. This is demonstrated by increasing research on integrating 21st-century skills in education policy, curriculum, and assessment (Roshid & Haider, 2024). Through 21st-century skills, students can utilize their knowledge, critical thinking, new technology, and creativity (Atasoy et al., 2023). 21st-century skills involve an extensive series of skills, including collaboration, communication, literacy, social culture, creativity, and critical thinking (Weber & Greiff, 2023), where this skill is one of the modern movements that is very important to support teachers and students in the school environment (Ahmed et al., 2022). Students must learn 21st-century skills to prepare themselves for the future, whether for higher levels of school, work, or society (Alismail, 2023). Therefore, it is crucial to teach 21st-century skills in higher education (Prastyaningrum et al., 2024) and elementary education (Watson, 2020). Moreover, it is very important to be taught in early childhood education (Sylva et al., 2020).

Early age is a golden age, where growth and development occur very rapidly (Kol & Tunçeli, 2022) So it is very important to get support, especially in education (Pangarti & Yaswinda, 2023; Prastyaningrum et al., 2023). Their growth and development are influenced by several factors, one of which is stimulation (Pem, 2015). Stimulation in early childhood has a great influence on child development. A child's development will greatly influence the acquisition of cognitive and non-cognitive abilities in the future (Black et al., 2017), where this ability plays an important role in future success (Briones et al., 2021). Given how important skills are for a child's future, stimulation of the skills they have is very much needed. The right skill stimulation strategy will encourage children's skills to the maximum. This underlies the emergence of a conceptual framework with the STEAM approach. As has been widely conveyed, the STEAM approach is suitable for skill stimulation in early childhood.

21st-century skills involve four major skills: communication, collaboration, critical thinking, and creativity, better known as the 4Cs. To stimulate 4C skills in children, teachers must also have good communication skills (DeCapua & Tian, 2015). Teachers are role models for students when in class, not only in the teacher's ability to communicate, but also to foster critical and creative thinking in children. It is necessary to design a learning environment that involves experimentation, exploration, expression, and collaboration to foster critical and creative thinking in children (Glezou, 2020). The learning environment must also accommodate children's interaction in a social learning environment. Through play and imagination activities, children can think creatively and critically in solving problems (Leggett, 2023).

Learning environment design for children can be integrated with science, technology, engineering, art, and mathematics, known as STEAM. Through STEAM learning, students can experience learning where the elements of science, technology, engineering, art, and mathematics can support each other (Al-Mutawah et al., 2022). Initially, the STEM concept, without involving art elements, was developed in the world of work, especially the industrial sector. However, over time, this concept began to be adopted in education (White, 2014). STEM is the basis of STEAM, with additional art elements. However, research related to transforming STEM into STEAM is still being carried out (Radziwill et al., 2015). However, it cannot be denied that art elements cannot be separated from science, mathematics, and technology learning.

Some literature writes that students are less interested in learning science and mathematics because of the lack of learning designs that can connect the two (Kelley & Knowles, 2016). Therefore, the STEAM conceptual framework is important because it can help teachers implement STEM pedagogy in the classroom (Nayem & Hossain, 2023). The prepared conceptual framework must fulfill all the elements included in STEAM education, but must still be based on the educational curriculum framework in Indonesia (Sujarwanto & Sanjaya, 2021).

The STEAM education concept will have a positive impact on early childhood development. Young children are individuals who are persistent and diligent in building designs; they will try to improve it when what they build is not according to their wishes (DeJarnette, 2018b). This positive personality must be supported by a learning environment that can support its development. Therefore, the STEAM learning concept should be integrated into learning activities (Ng et al., 2022).

During the research process, researchers have not found any studies related to learning environments that integrate STEAM, especially the field of physics in the learning process, which can stimulate 4C skills in early childhood. So far, the studies we have found discuss children's creative participation as the forerunner of 21st-century skills (Nikkola et al., 2024). There are also studies related to the quality of an educational process that supports the development of 21st-century skills in the preschool years (Sylva et al., 2020). Even though there is research that has discussed the influence of STEM on creativity in early childhood (Üret & Ceylan, 2021). There is no visible integration of physical science learning in it.

Based on this description, in-depth research is needed regarding designing a STEAM-based learning environment to stimulate 4C skills in early childhood. This process, of course, requires an appropriate STEAM conceptual framework. The importance of a STEAM conceptual framework in designing a suitable learning environment for young children is of great interest. It cannot be denied that in the future, humans must be able to connect knowledge to the real world, for example, in solving problems in the world of work (Asunda, 2014). Communication, collaboration skills, critical thinking, and creativity must, of course, support this ability.

Considering the importance of a STEAM conceptual framework in learning activities, we aim to design a STEAM conceptual framework that focuses on physics but is still connected to the other four fields of science. This conceptual framework will foster cognitive, language, psychomotor, and social-emotional understanding. Apart from that, we also hope that this conceptual framework can become the basis of literature for teachers when designing a learning implementation plan in the classroom.

STEAM and 21st-Century Skills

Early childhood is an age level that is very rich in creativity. Qualified educational support will significantly influence the development of children's creativity. Integrating STEAM-based learning in several disciplines will help encourage creativity in early childhood (Ng et al., 2022). STEAM education is said to be an approach to learning activities. In its implementation, through teacher involvement, children are expected to develop so-called 21st-century skills (Bybee, 2013).

Integrating STEAM into learning activities at the early childhood level is very necessary. Through STEAM-based learning activities, children can explore, experiment, and use various tools to analyze a problem (Aktürk & Demircan, 2017). In its implementation, children are given an engineering design problem related to a story. The following week in art class, students work collaboratively in small groups to design, develop, and test the engineering designs they have developed. Through STEAM learning, young children can learn about STEAM initiatives and develop curiosity, exploration, experimentation, observation, and critical thinking skills to engage in engineering design-based activities (DeJarnette, 2018a).

Integration of STEAM in Early Childhood Learning

The concept of integrating STEAM into early childhood learning is very important to continue to develop. In several studies, it has been found that early childhood creativity will be increasingly encouraged when learning can be integrated with other scientific disciplines (Ng et al., 2022). The process of integrating STEAM into learning can be done by highlighting everyday phenomena that occur in the surrounding environment, for example, by adopting the use of science topics, such as the water cycle, life cycles, and habitats (Smith & Cline, 2016), where the process is explained in the context of STEAM.

One of the characteristics of integrated STEAM education is the articulation of various fields of knowledge (Silva-Hormazábal & Alsina, 2023). STEAM integration in learning focuses on innovation and applied design processes. Not infrequently, this solution to complex contextual problems involves modern equipment (Kennedy & Odell, 2014). The STEAM integrated learning process can also be carried out by giving children time to explore and be creative; then, questions will automatically flow about the world around them (Lindeman et al., 2014).

Integrating STEAM in learning activities is greatly influenced by the individual characteristics of teachers and students (Al-Mutawah et al., 2022). In addition to the characteristics of teachers and students, the role of school management and the equipment and infrastructure also influence this process (Gamette, 2020). With the integration of STEAM in learning, it is hoped that it can provide new facilities so that students can apply various scientific disciplines to learn new things.

STEAM Instructional Approach

Implementing STEAM-based learning in schools certainly has its challenges, especially for teachers, not only in terms of delivering material but also in terms of technology integration and assessment (Herro et al., 2019). This is also supported by research results that show deficiencies in measurable learning outcomes (Perignat & Katz-Buonincontro, 2019). Based on this fact, the conceptual model must be clearly defined, and teaching content must also be considered when implementing STEAM teaching practices (Quigley et al., 2017).

The approach model we designed begins with analyzing the scene setting in learning. Scene setting allows students to explore the environment (Kerr et al., 2013). Scene setting is a critical initial stage of exploration. The accuracy of scene setting is a significant factor in developing narrative knowledge and storytelling performance among children (Berman, 2014). Analogous to this understanding, the accuracy of scene setting in terms of STEAM-integrated learning is also critical.

Investigation is one thing that must be included in the STEAM integrated learning process. Investigation is needed to build the character of thinking like a scientist who always approaches a systematic way of thinking (Cavadas et al., 2019). Besides that, with investigations (for example, in problem-based learning), student's knowledge base and skills will be increasingly honed (Beringer, 2007).

The STEAM instructional approach also involves a problem-based learning model. By starting with determining the appropriate scene setting and supported by investigative activities based on the scene setting that has been determined, students are invited to analyze the problems that occur and think creatively about how to solve them. In the future, this will positively impact students' creativity in finding solutions to problems (Chan, 2013; Ersoy, 2014).

The learning implementation design must be determined to achieve the targeted learning outcomes. Based on the scene setting determined at the beginning, students are given questions to explore their basic knowledge further. The teacher's role is to provide the guidance and instruction needed so that new concepts can be further expanded (Fitria et al., 2018). Apart from that, it also ensures that students retain essential information in learning.

This learning design is student-centered. By focusing learning activities on students, it is hoped that students can develop their abilities and skills to achieve their goals. Students will learn to communicate and express their opinions or thoughts regarding events that are a point of attention. These skills can be taught effectively in various disciplines (De La Harpe et al., 2000). This is also an important consideration when implementing STEAM-integrated learning.

2. METHODS

This research applies a 'best-fit framework synthesis' approach (Carroll et al., 2011, 2013). This approach synthesizes frameworks and thematic analysis techniques to develop the best conceptual framework in early childhood and STEAM research. This research began with the targeted identification of relevant models and theoretical qualitative studies (i.e., studies that collect data through in-depth interviews, focus group discussions, observations, etc. (Patton, 2014) That addresses appropriate STEAM Learning. Next, all physics concepts from existing theoretical models are extracted and analyzed to produce concepts and sub-concepts that are adjusted based on their suitability and incompatibility and their definition with the STEAM approach.

In the next step, data from the included qualitative study results section is extracted to analyze the concepts and sub-concepts of the material and the learning stages. This data consists of the author's analysis and formulation results from participant interviews. Interviews, in-depth observations, and literature review support were used to strengthen the conceptual framework in this research. Interviews and observations were conducted to obtain information on implementing learning with the STEAM approach. The results show that learning with the STEAM approach has been carried out, but is not optimal due to the absence of a clear and structured conceptual framework design to facilitate the learning process. In order to compile this conceptual framework design, literature studies are also used as a source of theory. In-depth interviews aim to explore respondents' points of view, experiences, feelings, and perspectives in detail (Boyce & Neale, 2006). This method is discovery-oriented to obtain detailed information about the research topic. An in-depth observation process is also necessary to strengthen the interview results. Observations must be carried out systematically, have clear objectives, and have a scientific basis (Kumar & Sharma, 2023). Both methods are supported by a literature review to formulate a more conceptual framework for the STEAM structure.

3. FINDINGS AND DISCUSSIONS

The STEAM-based learning design is designed to focus on learning aspects and consider social-emotional aspects. This follows the objectives stated at the beginning. In its implementation, students are allowed to explore further the scene setting that has been determined. Communicate with friends in the same class, and ask questions related to whatever they want to know. This design must integrate five different scientific disciplines developed through social discourse.

Activities designed based on a predetermined scene must involve science, technology, engineering, art, and mathematics content. The five STEAM disciplines are integrated with an emphasis on science on basic physics concepts. The scene setting that is set must be in harmony with real life. This activity is in line with the concept of renewable energy sources. Where the physics concepts of force and motion are involved, technology is used to design a generating system, and measurement is a mathematical concept. Students can explore their creativity to build a diorama of a solar power generation system by combining their artistic ideas. Of course, the implementation remains under teacher guidance and within the learning capacity of early childhood.

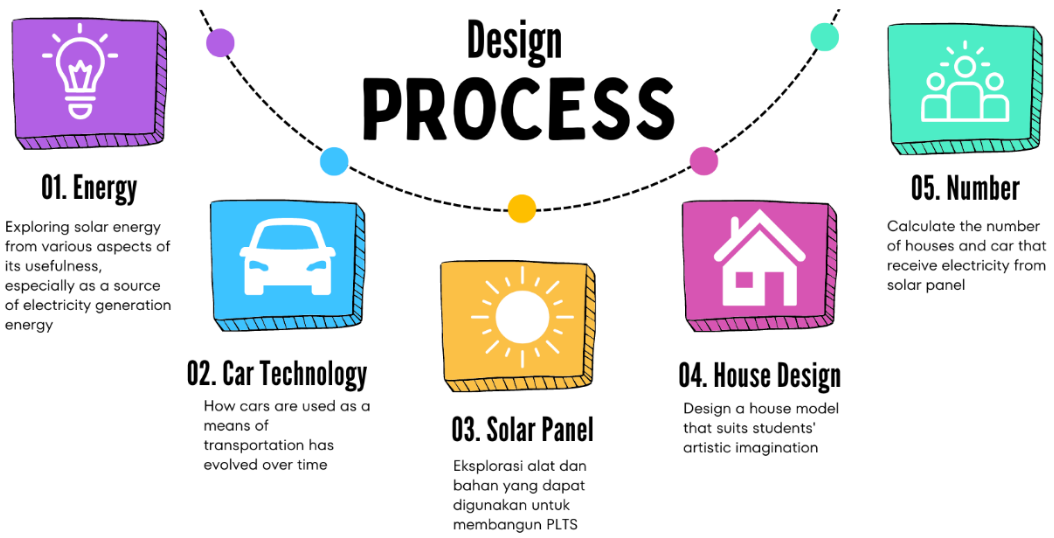

Figure 1. STEAM design in early childhood learning

Figure 1 shows the design of STEAM-integrated learning activities. This design is based on a scene about solar energy and its use as an electric power generator. The choice of scene setting was motivated by the current widespread renewable energy development. Solar energy is a promising renewable energy source that is freely available and can be used to overcome the problem of the long-term energy crisis (Kannan & Vakeesan, 2016). Even though the total solar energy that can be utilized is only 10% of the total energy, even just 0.1% can meet all the power needs on the Earth's surface (Chen, 2011). This fact will provide a special attraction for students and raise many questions from them, which will cause the scene setting related to solar energy to be explored further.

In implementing STEAM education, cognitive, language, and psychomotor elements must also be involved. Exploration of scene settings that involve cognitive and language elements will train students' critical thinking and communication skills. Apart from that, the touch of art in the concept of solar energy provides its color in training students' creativity. An in-depth exploration of solar energy is expressed in images that demand imagination. Students are expected to be able to create something new based on their thinking from previously studied themes (Lilly, 2014).

Several STEAM learning activity designs are written in Tables 1, 2, and 3. Each table provides a detailed description of the process of integrating STEAM into learning activities. Tables 1, 2, and 3 are a single conceptual framework that cannot be separated from each other. Table 1 is a phase to identify the extent of children's knowledge regarding energy and electrical energy. Table 2 is an exploration phase related to the use of electrical energy itself (in this case, the use of energy in an electric car is taken as an example). Table 3 is already leading to practical exploration, where children can work on a simple project related to renewable energy, in this case, a solar power plant.

Table 1. STEAM integrated learning activity design, Phase 1

Integrated STEAM on Learning Program			STEAM Content
Objectives	**KPIs**	**Question to Reflect**	
Identify solar energy and its benefits	1. Identify what energy sources exist in nature 2. Identify the benefits of solar energy 3. Identify electrical energy 4. Identify the benefits of electrical energy 5. A wise attitude in utilizing energy and electrical energy	1. Can we not see the objects in our classroom? 2. Why can we see it? 3. What is one of the benefits of solar energy? 4. Are there any other benefits? 5. What is electricity used for at home and school? 6. What if there is no electricity? 7. Where does the electricity come from? 8. What attitude should we have when using electrical energy?	**Science (Physics)** 1. Energy 2. Calories 3. Electricity
Instructional Approach	**Problem-Based Learning with Inquiry-Based Model**		
Learning Domains	**Affective, Cognitive**		
4C Skills	**Communications, Critical Thinking, Creativity**		

In Table 1, students' fundamental knowledge about energy is explored more deeply in stage one of learning. Several questions are asked to stimulate students' 4C skills. Activities carried out at this stage include discussions and questions, and answers. Discussion and question-and-answer activities will make it easier for a teacher to know how much students know and how emotional they are (Ahn, 2005; Denham et al., 2012).

In this first stage, the physics material studied is related to energy, heat, and electricity. Students will learn more about the benefits of energy, how energy exists, and their wise attitude towards energy use. Through this activity, the teacher explores knowledge about the concept of energy. Energy is only a change from one form of energy to another (Halliday et al., 2013). From here, students continue to explore how humans should behave in utilizing energy. Arouse students' emotions by providing several simple case examples related to energy use. Arousing students' emotions is very important because it will be very beneficial in building a life in society (Denham, 2003).

Apart from learning about energy, students will also learn about heat, a form of energy. Where does heat come from, and what benefits can humans derive from its presence? Because the scene setting related to discussing energy is directed at solar power plants, material about simple electricity will also be introduced to students.

As we already know, human life will be close to electricity. Almost all human activities use electricity. Getting to know electricity needs to be done from an early age. There are benefits to electricity and dangers that arise if you are not careful about using it. Students are also introduced to equipment that uses electricity, specifically equipment that converts electrical energy into heat. This aims to maintain continuity with the energy and heat material that has previously been studied.

Table 2. Design of STEAM-integrated learning activities, Phase 2

Integrated STEAM on Learning Program			**STEAM Content**
Objectives	**KPIs**	**Question to Reflect**	
Technology in a car	1. Identify the benefits of a car 2. Identify how the car can run 3. Identify what happens if the car breaks down 4. Be wise when driving.	1. What are the types of cars? 2. What are the benefits of a car? 3. How can a car run? 4. What damage to the car is known? 5. What if the car cannot run? 6. What should our attitude be when driving a car?	• **Physics** Style Motion Gravity Pressure • **Technology** Technology in cars in general and electric cars in particular
Instructional Approach	**Problem-Based Learning with Inquiry-Based Model, Problem Solving**		
Learning Domains	**Affective, Cognitive**		
4C Skills	**Communications, Critical Thinking**		

The second stage is the stage of exploring and stimulating students' knowledge of technology, which is shown in Table 2. It cannot be denied that young children will not be far from technology (Clements & Sarama, 2002). For example, Google's search engine technology can help someone find the answer to a question (Kermani & Aldemir, 2015).

In this second stage, the focus of the discussion on technology is on using technology in a car. Students explored how a car can run, and why cars are always placed on the ground, not floating like astronauts, and were even explored further by involving the setting of an accident case. Physics concepts can be learned through daily activities (Areljung et al., 2023).

Another thing that can also be explored in this second stage is the fuel for a car, introducing various types of fuel as a result of natural resources. At this exploration stage, students are directed to understand the importance of using energy wisely. This aims to realize the importance of preserving natural resources for used (Pliogou, V., Kountouroudi, A., Kamperidou, I., Coumpa, A.-I., & Coumpa, 2017). It is crucial to explore how far they know about fuel in cars; it can even be continued with exploration regarding what would happen if car fuel no longer exists. This exploration aims to direct students to knowledge about electric cars.

Apart from that, the teacher also gives simple problems about a damaged car. What is our solution to this problem from an early childhood perspective? Problem-solving abilities are very important to explore because this will be very useful in resolving conflicts, for example, with peers (Mayeux & Cillessen, 2003).

Remember to include affective elements in every stage of learning. If the previous stage was related to wise attitudes in utilizing energy, then at this stage, the exploration is directed at how much students know about good attitudes when driving.

Table 3. Design of STEAM-integrated learning activities, Stage 3

Integrated STEAM on Learning Program			STEAM Content
Objectives	**KPIs**	**Question to Reflect**	
Making a diorama of a solar power generation system	1. Identify the benefits of solar energy 2. Identify power sources 3. Prepare the tools and materials needed to make a solar power generation system diorama 4. Preparing 3D designs for dioramas 5. Ability to discuss with friends and ask teachers. 6. Good attitude in asking questions and discussing	1. What are the tools and materials for making a diorama? 2. How to make a diorama? 3. What color is the house in the diorama? 4. How are the houses arranged in the diorama? 5. How many houses, trees, and people are in the diorama? 6. How many cars are there in the diorama? 7. Which house is bigger?	**Technology** Techniques for making solar panels and dioramas **Art** Creativity in choosing colors, arranging the location of each house, tree, person, and vehicle **Mathematics** 1. Recognize the number of houses, trees, people, and cars counted 2. Know the comparison
Instructional Approach	**Problem-Based Learning with Inquiry-Based Model, Problem Solving** **Cooperative Learning**		
Learning Domains	**Affective, Cognitive, Psychomotor, Language, social-emotional**		
4C Skills	**Communications, Critical Thinking, Creativity, and Collaboration**		

The third stage is the final stage in STEAM integrated learning activities, with a scene-setting of solar energy and its use (Table 3). At this stage, the activities are focused on exploration and involve group activities. Students are directed to collaborate with other students to compile a solar power generation system diorama. Under teacher guidance, students practice communicating with teammates to solve a problem. They also practice thinking systematically because it relates to the arrangement of a diorama. Systematic thinking is critical to develop because this is linearly related to logical abilities (Haloho, 2022).

In the third stage, students are asked to be creative according to their imagination in making dioramas. Choose colors that suit them and adjust the harmony between one color and another. Stimulating students' abilities in art will influence students' self-confidence in the future (Twigg & Garvis, 2010).

Apart from engineering and art, this stage also studies simple mathematics. Early childhood school students are starting to recognize simple numbers. Apart from that, they also learn about comparisons. Mathematics is a very important cornerstone of curricula worldwide (Linder et al., 2011). However, even so, learning mathematics must still be carried out in a fun way.

The overall results in this article (including Table 1, Table 2, and Table 3) introduce STEAM activities in the scope of early childhood education. These activities can help students integrate science, technology, engineering, art, and mathematics to achieve certain targets. STEAM content, context, and instructional approaches are detailed in a theoretical and conceptual framework. This framework was developed as a recommendation for teachers and curriculum developers regarding STEAM education practices in learning in early childhood education. This conceptual framework is in line with the design of the conceptual framework that has been previously designed (Al-Mutawah et al., 2022). In previous studies, the design of the conceptual framework was directed at the construction and development of beach houses. However, this study's conceptual framework focused on solar power plants. In addition, the conceptual framework in previous studies can be used in learning as a whole, but this study is more focused on the level of early childhood education.

4. CONCLUSION

In order to face the increasingly rapid changes in the world, it is very important to equip the new generation with 21st-century skills. This study explores the capacity to design a conceptual framework with a STEAM approach in early childhood education. This study utilizes STEAM activities by taking the topic of solar power plants. The results of this study are a conceptual framework design that refers to the STEAM approach. This conceptual framework is divided into three continuous phases and has also been designed to stimulate and explore 21st-century skills in early childhood. The conceptual framework that has been prepared can be used directly and applied to other topics. The drawback in this design is that the conceptual framework is only accompanied by Key Performance Indicators. Hence, it needs to be equipped with an assessment model in each phase to measure student success.

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