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Enhancing Early Childhood Education with Active-Based STEM And STEAM Methods

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ABSTRACT

Science, technology, engineering, arts, and mathematics (STEAM) education in early childhood education (ECE) is one of the strategies to nurture 21st-century learning skills, mainly critical and creative thinking skills. It takes effort to implement this education approach as teachers and parents have less knowledge on how to deliver the information to the kids. Therefore, several active-based learning methods were introduced to ease the learning process and make it memorable. This study discusses the advantages of Science, Technology, Engineering, and Mathematics (STEM) and STEAM education in ECE and the effects of active-based learning commonly used in delivering STEM and STEAM education. STEM and STEAM education in ECE can train kids to develop better scientific skills while simultaneously expanding their creativity limitless. Meanwhile, the four types of active-based learning methods have scientifically proven that kids' participation in STEM and STEAM areas has enhanced teamwork, increased motivation, and improved interpersonal and soft skills among kids.

Keywords:
Early childhood education; STEM; active-based learning

1. Introduction

STEM education is viewed as a lifelong education inculcated through formal learning based on curriculum, non-formal through co-curricular activities, informal through indirect learning from early age till tertiary and finally, at the community and industry level [1]. In recent years, STEM education has been widely implemented in ECE as one of the initiatives to stimulate children's knowledge in the following subject fields. According to Rasmani *et al.,* [2] after a few research and attempts to provide professional STEM programs and activities, emerging trend requests to include the art (A) field into the existing integrated subjects are performed. STEAM is seen as an approach to improving children's real-life experiences through relevant and appropriate experiments. It is well known for promoting a learning process that allows children to explore and discover, question, communicate,

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research, application on innovative building skills, and reflection [3]. According to Iskandar [4], the five important characteristics involve all the significant tasks, such as connecting the existing knowledge with what needs to be learned, researching sources from concrete to abstract understanding, discovering the possible solution for the subject problems, constructing a solution model required for the problem and finally, demonstrating their communication and collaborative skills by collecting productive feedback from each other.

Since the first year of STEM was introduced in the 1990s by National Science Foundation (NSF), which was previously known as SMET [5], multiple ongoing experiments and research have been conducted about the impacts of STEM and STEAM education among students and teachers. Although integrated-subjects-education seems to get tremendously accepted and phenomenal, most researchers have only focused on primary and secondary school. Only a few studies have focused on ECE, especially STEAM education. A study by Aktürk *et al.,* [6] about the Turkish early childhood curriculum in STEM perspectives has mentioned that STEM mainly focuses on play-oriented learning. This enables the children to develop critical thinking skills, construct plans, improve expression, ask questions, investigate, solve problems, and find solutions. Learning through experiences in an active environment can be an effective approach to implementing STEM in ECE Soylu [7].

Moreover, preschoolers are recognized as eager and undoubtedly excited young learners when they are given opportunities to explore new subject fields. Hence, unlimited exploration is important in developing the competencies in STEM education at an early age. Young learners naturally possess science foundation knowledge and engineering concepts by asking questions related to animals, observing and differentiating the uniqueness in every human's eye and asking "why" questions [8]. In this particular case study, while STEM is highly in need of students' participation, it is also crucial to improve learning trajectory skills and understanding within the educators to provide students with high-quality learning. Several studies have shown that the interest in STEM education has significantly grown in developing countries such as India and Malaysia [9-10]. In contrast, young learners in western nations such as Australia have seen a decline in STEM enrolment [11].

The beginning process of introducing the STEAM concept to children is not an easy task because it requires a lot of mindful skills and provides suitable hands-on material for the best learning experiences [12]. A few researchers have proved that STEAM from early exposure can improve children's interest in learning STEM and provide them with advanced preparation for 21st-century demands. Dejarnette [3] focus on the importance of STEAM for ECE, which involves providing hands-on materials for preschool teachers to implement STEAM at school, showed that both teachers and students were thrilled by the teaching aids and strongly agreed that this alternative could bring success for both sides. Munawar *et al.,* [13] also revealed that there is a positive impact on future education with the implementation of STEAM experiences at an early age. Hence, it can be concluded that the initiative to involve the kids in STEAM cannot be put aside.

This study aims to analyze the impact of implementing STEM and STEAM in ECE to help many other researchers understand the overview of STEM and STEAM in ECE. It also aims to foresee the development process of STEM education, analyze various methods used, especially active-based learning in STEM for ECE and summarize the importance of STEM in ECE. The objectives are as follows: to analyze the effectiveness of STEM and STEAM in ECE, to determine various active-based learning approaches used in implementing STEM and STEAM in ECE, and to summarise the importance of STEM and STEAM in ECE.

2. The Importance of STEM and STEAM in ECE

STEM in ECE brings many benefits to many parties. For example, a study by McClure *et al.,* [14] has states that parents and teachers will acquire a great understanding of their children's learning development and be able to track their children's educational progress without worrying about their constructive development. In the meantime, when engaging in a STEM learning environment, there will be an opportunity for parents and teachers to indirectly upgrade their additional scientific skills as much as their children's. However, many parents and teachers are experiencing low self-esteem and anxiety when engaging in STEM education. The issue usually occurs when they try to transfer STEM knowledge to the children for basic understanding [14]. Therefore, the opportunity to learn STEM has been widely opened for parents, teachers, and kids, especially in this modern era with advanced technology, where all educational resources can be found and applied everywhere. In line with the 21st-century demands, STEM in ECE can develop mathematical, science and engineering skills at a very young age that will help them to learn better and adapt to what they can do [15]. For example, innovation, conducting experiments, making observations and conclusions, analyzing data, planning strategy, critical thinking, collaboration, and making predictions about what they have found [14]. What makes STEM important to start at a young age is all the active-based learning that has been used in-class sessions widely by teachers pertaining to the cognitive, constructivism, and collaboration of kids.

3. The Effectiveness of STEM and STEAM Education

Applying STEM and STEAM education at an early age is essential. Dedicated researchers have proved it in terms of encouraging interest among students and developing critical thinking skills broadly since it has been extended from primary and secondary education to ECE [16]. What has been said to inspire students' interests is that STEM and STEAM can effectively bring preschool students out of their comfort zone because they are not only playing but also learning and promotes creativity [17]. According to Buchter *et al*., [18], the STEM and STEAM approach to preschool students has shown that there has been a significant effect in improving the ability of object classification in terms of big-small size, basic colors, long-short objects, far-near distance, thick and thin to a more specific scientific and mathematical way such as more or less, greater or lesser and sooner or later. Furthermore, the STEAM approach used in this study has remarkably led to more valuable skills, such as investigating and generating scientific and engineering skills. This is based on the study conducted by Rasmani *et al.,* [2], where data was obtained from Kampung Panjang 03 Kindergarten Ambarawa which has found that children from this study area have difficulties in classifying objects based on their specific category. Then, STEAM approach was applied to see if it could affect the specified issue. According to the data, it showed that the experimental group had shown an increment in its mean value through the practicality of the STEAM approach compared to the control group. Furthermore, based on the great differences between the two study groups, the STEAM application has positively impacted the children's ability to classify objects.

In addition, one more study by Huri and Karpudewan [19] about Evaluating the Effectiveness of Integrated STEM-lab Activities for the topic of Electrolysis has shown that the implementation of Integrated STEM-lab has improved the understanding of the selected topic among the targeted audiences. The quantitative and quantitative data was collected using One-way Multivariate Analysis of Variance (MANOVA) and interviews respectively. The result shows that the students in this study elaborated their understanding in detail and often referred to the STEM-lab Activities prior to their understanding improvement.

The effectiveness of applying STEM and STEAM in education has been proven by many researchers from all countries, in line with the idea of STEM implementation to prepare skilful

generations for the future and create future engineers [20-22]. Baharin *et al.,* [23] stated the STEM approach could accumulate students' knowledge and skills with how the teaching strategies were applied by the teachers as it was proven that the methods are relevant and suitable to the preschoolers' interest, which is to build an inquiry. Meanwhile, the STEAM approach will most likely encourage students to explore the STEM field more creatively, fitting the "Arts" element [2].

To see the effectiveness of the integrated project-based learning model STEM in improving the creative thinking skills, a study was conducted in Tersono District, Batang Regency, with students in grade 4 by Akhmad *et al.*, [24]. Learning activities begin with the basic introduction of light, such as movement, reflection, refraction, and penetration of lights through objects, followed by activities to increase students' creative thinking skills. A research study showed that in the experiment and activities before STEM-integrated Project-Based Learning (PjBL) was applied, the tests for students' creative thinking abilities only reached the average satisfactory point, 59.75 before improving to an outstanding category with a point of 80.5 after applying it. Based on the data, it can be concluded that there are notable differences in the results of students' creative thinking abilities skills that applied STEM-integrated PBL during learning activities and suggested that this approach should be productively used in a topic.

4 Active-Based Learning Approaches Used in Implementing STEM and STEAM in ECE

The top active-based learning commonly used in ECE while implementing STEM and STEAM education is project-based inquiry learning (PBIL), game-based learning (GBL), project-based learning (PjBL and problem-based learning (PBL). The following explains about PBIL, GBL, PjBL and PBL that are appropriate to be implemented.

4.1 Project-Based Learning (PjBL)

PjBL fits the current national request to associate with 21st-century learning, emphasizing student-centered learning [25]. It has been found that the PjBL approach in STEM has a positive correlation between science content learning and participating in the PjBL approach [26]. STEM activities with the PjBL approach are not limited to one specific disciplinary area, but it often covers multiple and will take more than one week up until a month. Teaching aids are said to be very useful in easing the learning process and can make learning a fun journey as stated in article by Ambarini *et al*., [27]. Therefore, many researchers have been known to include real-world activities with hands-on materials as teaching aids in STEM education. For instance, using the audiovisual as a teaching aid in mathematics is favorable in developing students' level of thinking and is effective for primary school students in grades 7-9 [28]. It is correlated with the use of media graphics as a teaching aid and has shown effectiveness in increasing the academic achievement of primary school students in Indonesia [29]. The addition of teaching materials to STEM activities along with PjBL is essential, as using them requires critical thinking, problem-solving, collaborative, and communicative skills, which is why PjBL seems more approachable and reasonable to connect with 21st-century learning skills. Those elements might be a challenge in education, which makes some people think that this approach only matters in higher grades and does not focus on early childhood education. However, there has been a shift due to the overwhelming demands and challenges in education. There is a need for the implementation of PjBL in early childhood education as it prepares learners for their future education. Incorporating PjBL in kids allows them to develop their collaboration skills which lead them to be actively engaged in learning sessions [30]. Hence, applying the PjBL approach was greatly created and organized for both teachers and kids. Before the class starts, the teachers or

facilitators of the class will create a mind-provoking question to begin the class session. The question should be related to their real-world experiences and able to trigger the kids' anticipation. In PjBL, continuously asking them will help intrigue their interests, especially the young learners, because they can relate to their daily environment. To make the teaching session memorable, PjBL usually comes with concrete product involving real-world experiences and mostly authentic tasks and setup [31]. By that, kids are encouraged to apply all 21st-century learning skills, such as critical thinking skills, collaboration, and communication. According to a study conducted on children in one of Indonesia's kindergartens, providing PjBL helps improve children's cooperative skills [32]. By exposing the kids to information-seeking through interaction between group partners, they start to investigate using their prior knowledge while the teachers act as facilitators, guiding them before the brainstorming session begins and eventually assisting them in finding a solution [31].

Other studies have reported PjBL in IT Fathul Ilmi Kindergarten develops not only children's early mathematical abilities but also builds interaction, communication, and collaboration skills, as well as the character traits of caring and empathy for friends. The study was conducted by plan, do, see until the redesign stage. Each stage is adjusted to the characteristics of the child. However, the limitation is that the research location is foggy in collecting data, so not all children are allowed to be at school. Nevertheless, the results contribute to the development of knowledge about the process of implementing PjBL in kindergarten [33].

4.2 Game-Based Learning (GBL)

GBL is one of the most suitable learning methods that match Alpha generations and was believed that including games in the class session could be more interactive and suited [34]. With the widespread use of technology, a student at a young age has been exposed to and sharpened their tech skills and has already taken multitasking to the next level [34]. For example, they can be listening to lectures while checking emails, texting, tweeting, and browsing the internet at one time. Some students even search for extra information about their ongoing lecture online instead of asking the lecturer while listening to the session [35]. However, before further discussing GBL, it is crucial to extinguish the terms GBL and gamification to avoid any misuse. Table 1 shows the differences between GBL and gamification.

Including games in a class lesson can improve the quality of learning activities and the kids' motivation. According to Al-Azawi *et al*., [36] practicing games in education has been practical to researchers for over twenty years because games are undeniably fun and stimulating for participants. It does not require researchers to achieve participants' attention and focus for too long. Early childhood is a critical time for developing motor skills. By inserting GBL in ECE, the kids are exposed to learning activities based on their nature, which is play, known to be an enjoyable and spontaneous activity for their age. GBL appears to contribute to improved learning performance by allowing kids to practice cognitive, physiological, affective, behavioral, social, and soft skills that lead to critical thinking and problem-solving through trial and error [37].

A previous meta-analysis study conducted by Behnamia *et al.,* [38] established the effect of using GBL facilitating critical thinking skills. GBL is trusted to improve learning motivation, as when the kids are in the middle of games, their concentration and focus level are higher compared to the traditional method [39]. However, despite the motivational impacts, there is a need to focus on the kids' academic performance to avoid a total waste of the efforts and investment made on software and hardware. It could be a very challenging job to convince the teachers.

Behnamnia et al., [38] provide a regular systematic review of the literature and analysis of state of the art in Digital Game-based Learning (DGBL) which purposely to present the latest developments

and trends through the review of experimental research related to the use of digital games based on ECE at the preschool level from 2 to 6 years of age. The study concludes that the use of DGBL can actively strengthen thinking skills and learning in childhood.

Table 1
The Differences between GBL and Gamification

Term	Definition	Concept
Game-Based Learning (GBL)	An approach using real digital video games as part of teaching aids in the learning process [36].	Using games as part of the learning process. Games and courses are combined. Involve gaming mechanics, elements, and thinking. Usually use any digital device, such as a computer, laptop, tablet, handphone, or social media platform. Often used for playing online games and video games in a teaching session. Improve learning experiences, and enhance long-term memory.
Gamification Learning	An approach using gaming elements in a non-gaming teaching context [36].	Transform the whole learning process into a game. Uses rule systems, user experiences, and social position. Include game concepts into learning contexts such as paintball, snakes and ladders, jigsaw puzzles, etc. Often get rewarded for good performances and attitudes, such as helping team members. Encourage participation, increase motivation, more interaction skills, and improve teamwork.

4.3 Project-Based Inquiry Learning (PBIL)

PBIL is a more flexible type of learning than the rest because this method emphasizes kids' science, higher-order thinking, creative thinking, problem solving, design, and construction skills as reported by Ng and Adnan [40]. After all, kids are given the opportunity to demonstrate things based on their existing knowledge [18]. Basically, PBIL consists of four active phases, namely, Inquiry, Exploration, Invention, and Reflection. It was first illustrated as the concept of building a ship. Starting with a mind-provoking question to include the "Inquiry" about a ship, such as "how do we build a ship?". After the "Inquiry" session begins, kids will explore how a ship functions, such as what will make it not sink, balance and is well built in the sea. Those explorations resulted in the planning of the design, size, and shape of the ship. Then, the "Invention" starts from the previous information and turns into material preparation, where all the suitable materials will be combined and built together to make a preferable ship. After the three phases are completed, the crucial part will take place to exchange opinions so they can reconstruct or rebuild a better ship. This phase is called "Reflection". To summarize STEAM concepts in one ship project, the balancing, design, size, shape, and finally building it are all considered part of Science, Technology, Engineering, Technology and Mathematics and A (Art).

Kids naturally explore and learn about what happens in their environments through inquiry, asking questions, and exploring. Since then, it has been strongly advised that PBIL be implemented in ECE. It has proved itself when the National Association for the Education of Young Children (NAEYC) has long advocated PBIL for early childhood, specifically from birth to age eight, as it helps learners develop their personal and social understandings of real-world objects [41]. Johnson *et al*., [42] described the first implementation of PBIL at the kindergarten grade level. The learning situation changes to a new environment as the kids begin to engage in discussion after the inquiry is given

through humorous questions. From there, kids began to develop mindsets by collaborating on ideas and opinions, as well as making personal connections with classmates [42]. Implementation of PBIL in STEM preschools in Taiwan found that kids who receive inquiry-based instruction possess a meaningful engagement in learning sessions [43]. Thus, it is reasonable to conclude that PBIL is important because kindergartners can successfully engage in inquiry processes and investigations. The National Association for the Education of Young Children (NAEYC) has long advocated inquiry-based learning for early childhood, specifically from birth to age eight.

4.4 Problem-Based Learning (PBL)

PBL is a learning event connected to the student's real-life experience, especially kids as the young learners are more likely to be actively involved in their surroundings. Since they tend to look for a solution to every problem, they manipulate, explore, and apply what they know and share them with family and friends which lead to a natural critical thinking and problem-solving process [44]. Note that PBL has quite a few similarities with PjBL. PBL requires many phases and stages to pass through the main project or problem. Before the teaching session begins, the class will start with a situation containing the main problem that directly goes to the kids' existing knowledge. For example, for young learners, the existing knowledge would be what they see and what they encounter daily around them. Unlike PjBL, PBL usually takes only a short time frame, but it can also be used effectively in the long term. Subsequently, PBL starts with brainstorming the idea for the solution to the given problem and collaboratively having an open discussion with the group. During the process, kids will be encouraged to speak, think and share ideas with their group members comprehensively. After elaborating on the idea among the group members, a strategic plan was made to find the important missing keys and started to brainstorm again about the possible solution and work towards the problem. After a suitable solution has been recognized, kids will have to present it, review what they gained from the previous discussion, apply the findings, and reflect on the results.

PBL as an approach in ECE has gained popularity because it allows kids to have critical observations of problems and issues, allowing them to improve the learning outcome by developing creative thinking skills [45]. Siew *et al*., [46] have contributed substantive proof that preschool teachers need to integrate PBL in their science lessons to inculcate scientific creativity among kids. PBL encourages kids to actively participate in the learning process by understanding the problems and thinking critically about how to solve them. A study on using visual elements containing problems conveys that kids make the learning session more meaningful and joyful [47]. Furthermore, brainstorming activities included in PBL allow kids to have good cognitive abilities, which can help them improve their social development. These reflect that PBL makes a good impression in developing problem-based STEM learning in ECE, as suggested by John *et al*., [48].

Table 2 shows the summary of the active-based learning commonly used in STEM and STEAM education for ECE. From Table 2, it can be seen clearly about the concept, time frame, teaching aids and benefits of PBIL, GBL, PjBL and PBL.

Table 2
Active-based learning commonly used in STEM and STEAM education for ECE

	Project-based learning	Game-based learning	Project-based inquiry learning	Problem-based learning
Concept	Focus on strategies to reach the main project's objectives.	Focus on games is used to enhance student learning.	Focus on strategies to reach the main project's objectives.	Focus on an instructional approach that enables learners to simultaneously develop problem-solving strategies, disciplinary knowledge, and research skills.
Time Frame	Long-term period (usually takes a month).	It can be played anytime. Depends on the learning objectives.	Long-term period (usually takes a month).	Short period but can also be used in the long-term period.
Teaching Aid	Hands-on material and technology related to real-life experiences. (Example: Teaching Modules with activities, mobile applications, computer games, crafts, and building blocks).	Usually based in IT and graphic gaming more than hands-on gaming. (Example: Mobile application and computer games).	Hands-on material and technology related to real-life experiences. (Example: Teaching Modules with activities, Jigsaw puzzles, lego, crafts, mobile application).	Hands-on and technology. (Example: Pasta Bridge, Straw Tower, Pressure Rocket, Ship).
Benefits	Enhance creative, problem-solving, and critical thinking skills.	Fun and increase participation. Improve learning experiences, and enhance long-term memory.	Get to explore their state of interest and widen their existing knowledge in depth.	Practice problem-solving in real-life experiences. Improve interpersonal skills.

5 Discussion

Active-based learning is seen as an approach where the learning is generated by the teacher and absorbed by the learner. In the simplest terms, active-based learning asks students to think, discuss, challenge, and analyze information. Meanwhile, passive learning requires the absorption, assimilation, consideration, and transfer of information. All of these can be implemented through STEM and STREAM approaches in all ages and it can begin in ECE.

According to previous research studies, STEM and STEAM education will continuously help kids contribute to the STEAM field with the help of various interactive active learning methods that promote fun, creative, dedicated, steadfast, focused, and committed ways of learning STEM and STEAM.

The kids will experience improved self-esteem, gross and fine motor skills, memory recall, problem-solving, communication, teamwork, social behaviors, engagement in and out of the classroom, concentration, and confidence. If that credibility develops early in life, during ECE, it may help them become people with 21st-century skills in the globalization era [32].

The power of active-based learning lies in some of the key principles. Note that these principles include the knowledge that learning involves the active construction of meaning where the learner links new information with what they already know, a distinction between the processes of learning facts and learning to do something, helping educators understand why a kid may know a set of facts but not how to apply them to a problem, an understanding that some learning is context-specific.

In contrast, others are more transferable to other contexts. Apart from that, there is a growing recognition that transferring information requires learned skills. A recognition that many individuals learn more with others than when they are alone. Development of children's learning skills that develop through active learning shows that this ability can develop through learning by doing, oriented to children's development holistically, based on games, cooperative/collaborative, and flexible in the sense that children can determine their learning activities to be carried out [49].

However, while it is probably useful for kids and teachers in the future, it might need to look at a few more issues to be taken into consideration. For example, the effect on academic performance when using the active-based learning approach because most of the methods utilized effectively help to increase motivation, behavior, and encouragement. Nonetheless, STEM and STEAM education, regardless of the learning method, always brings what the nation needs because it combines all the essential and crucial subjects since the world is now reaching the 21st century. It might be very challenging with the uprising of social media. Yet, the teachers in kindergarten are ready if, in implementing STEM in ECE, they are given the opportunity to be exposed to knowledge regarding STEM education [50].

6. Conclusion

In conclusion, STEM and STEAM in ECE must be highlighted and brought forward to nurture future generations from an early age. It will be easier for the kids to grow alongside the advancement of Science and Technology. This will be crucial in a world where Science and Technology have become greatly necessary, helping them to better prepare for their future. In addition, STEM and STEAM education will make them more competitive in engaging in their future working lives as they are equipped with advanced knowledge in Science and Technology. STEM and STEAM education will also provide the kids with multiple pathways to choose a career in their field of interest. Apart from that, the kids will be able to problem-solve on their own more rationally and logically as they were educated with STEM and STEAM knowledge. They will also be more independent in carrying out their lives and interacting with society and the community. Thus, this article can provide knowledge about active-based learning with STEM and STEAM approaches for early childhood.

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