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STEAM Education: A Pathway to Enhance Critical Thinking in Dynamic Elementary Classrooms

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Abstract
Developing 21st century skills is crucial for our future leaders. One effective way to foster these skills is through STEAM education, which combines Science, Technology, Engineering, Arts, and Mathematics to promote critical thinking and competency in learners. In this study, we conducted individual-based action research in a school located in Karachi, Pakistan to explore the incorporation of STEAM education in the country's education system. Our goal was to create a constructivist classroom environment that would promote experiential learning. The study involved 20 Grade VII female learners, who were studying Science and Mathematics. Over a period of 4 months, we applied STEAM activities in 2 cycles comprising of 9 lessons. We collected data through the application of the STEAM approach in the classrooms, using various tools including interviews, online quizzes, padlet, jam boards, and concept cartoons. We also used qualitative research methods such as field notes, anecdotal records, and rubrics to analyze the data. Despite facing challenges such as limited resources, lack of previous exposure to STEAM, limitations of the curriculum, and a shortage of professionally qualified teachers, we were able to achieve satisfactory results at the end of both cycles. The learners became more technologically adept, independent, and intrinsically motivated to learn. In conclusion, incorporating STEAM education in the Pakistani education system has the potential to create a more dynamic and engaging classroom environment that promotes critical thinking, creativity, and problem-solving skills in learners the STEM education is actually need of the students for todays world.

Keywords: *teachers' teaching techniques, teachers' assessment strategies, students' reading attitude and performance in English subject.*

1. Introduction

Critical thinking is an essential skill for students to develop to succeed in the 21st century. This assertion is supported by research, such as the comprehensive study by Dwyer et al. (2014), which emphasizes critical thinking as a crucial competency for navigating complex global challenges**.** However, traditional teaching methods may not effectively promote the development of critical thinking skills. The traditional teaching model often employs rote memorization and standardized testing, which may not engage students and foster the development of critical thinking skills (Wong & Wong, 2017). This limitation of traditional methods is further corroborated by Abrami et al. (2015), who found that explicit and purposeful critical thinking instruction is more effective than implicit approaches. One approach that has gained increasing attention in recent years is the integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education into the curriculum. Teachers can create an environment that encourages critical thinking and problem-solving skills by fostering dynamic elementary classrooms using STEAM frameworks. This aligns with the findings of Perignat and Katz-Buonincontro (2019), who observed that STEAM education enhances students' cognitive flexibility and innovative problem-solving abilities**.** On the other hand, the STEAM framework provides an interdisciplinary approach that emphasizes inquiry-based learning, creativity, and problem-solving skills (Choi et al., 2017). This interdisciplinary nature of STEAM is particularly effective in developing critical thinking, as noted by Henriksen (2014), who argues that integrating arts with STEM subjects cultivates more holistic and creative problem-solving approaches**.** STEAM education aims to promote critical thinking skills by allowing students to explore real-world problems through hands-on activities that require them to apply knowledge from multiple disciplines. This approach is supported by the research of Land (2013), who found that engaging students in authentic, real-world problem-solving significantly enhances their critical thinking abilities**.** Science, Technology, Engineering, Arts, and Mathematics (STEAM) education has become increasingly important in the global workforce, where proficiency in these subjects is becoming a necessity (National Science Foundation, 2019). This trend is further emphasized by the World Economic Forum (2020), which predicts that 85 million jobs may be displaced by a shift in the division of labor between humans and machines by 2025, while 97 million new roles may emerge that are more adapted to the new division of labor between humans, machines, and algorithms**.** As the world continues to become more technologically advanced, the need for individuals who can apply STEAM skills in their careers is only going to increase. In Pakistan, where the economy is rapidly growing, there is a need for a skilled workforce in these areas, particularly among the youth (Pakistan Economic Survey, 2021). This need is further highlighted by a study from the Asian Development Bank (2019), which found that Pakistan faces a significant skills gap in STEAM fields, with only 16% of university graduates in these disciplines. Therefore, it is crucial for secondary schools in Pakistan to offer STEAM education to their students to equip them with the skills they need to be successful in the future. In Pakistan,

where the economy is rapidly growing, there is a need for a skilled workforce in these areas. According to the Pakistan Economic Survey (2021), the government of Pakistan has identified the development of human capital as a key driver of economic growth, and STEAM education is a crucial component of this. This aligns with global trends highlighted by UNESCO (2019), emphasising the importance of integrating STEAM subjects to foster innovation and problem-solving skills essential for addressing complex global challenges. Furthermore, a study by the Lahore University of Management Sciences (LUMS) found that students with access to STEAM education were more likely to pursue careers in STEAM-related fields and had better employment prospects (LUMS, 2020). This emphasizes the importance of STEAM education in providing students with the skills and knowledge necessary for success in the workforce. Secondary schools in Pakistan are currently facing a significant challenge in preparing their students for the workforce of the 21st century. The traditional education system in Pakistan has been criticized for focusing on rote learning and memorization rather than promoting creativity, innovation, and critical thinking skills (Ali & Razzaq, 2021). This approach to learning may leave students ill-prepared for the demands of a rapidly changing global workforce, particularly in STEAM-related fields (Khalid & Ahmad, 2019). Therefore, there is a need for secondary schools in Pakistan to adopt a STEAM education approach to prepare students for the challenges of the future. This need is further emphasized by the Higher Education Commission of Pakistan (HEC) (2019), which stresses the importance of integrating STEAM education into the curriculum to produce skilled professionals who can meet the demands of the 21st-century workforce**.** In light of the above local and international research, it is clear that there is a need for secondary schools in Pakistan to adopt a STEAM education approach to prepare students for future challenges. By providing students with hands-on, real-world experiences that encourage creativity, critical thinking, and problem-solving skills, STEAM education can help develop a skilled workforce in STEAM-related fields, which is crucial for Pakistan's economic growth and development. This approach is supported by a meta-analysis by Abrami et al. (2008), which demonstrated that active learning strategies, central to STEAM education, substantially positively affect students' critical thinking development. Despite the potential benefits of STEAM education, there is limited research on the specific ways in which it can foster dynamic elementary classrooms and enhance critical thinking skills in the Pakistani context. Therefore, this study aims to explore the relationship between STEAM education and the development of critical thinking skills in elementary classrooms in Pakistan. Specifically, the research objectives are to investigate how STEAM education can provide learners with opportunities for life-long learning experiences with problem solving attitude.

1.1. Research Objective and Questions

- To examine how STEAM education can engage learners in critical thinking processes and inquiry-based learning.

- To assess how STEAM education can prepare learners for twenty-first-century challenges and contribute to their future success.
- To explore pedagogies and strategies teachers can use to incorporate STEAM into their daily science and mathematics lessons.
- To provide insights into student-cantered classrooms' benefits and how STEAM learning develops competent individuals in Pakistan.

By addressing these objectives, this study seeks to contribute to the development of essential skills among learners and promote a student-cantered learning environment in Pakistani schools. This would ultimately enhance the quality of education and prepare students for the handling the challenges of the today's world.

2. Literature Review

Integration of across multiple disciplines in education and embedding these with the 21st century skills makes room for innovation in a nascent mind. Knowledge, understanding of STEM education are important factors to be on this track. Using context for STEM is a challenge as the focus here is not only to get an understanding of terms, but to understand the issue to find its solution. "It is a challenge to understand that STEM is not just a slogan; its education does have a purpose. (Bybee, 2013)". Previously, Science, Technology, Engineering, and Mathematics were represented by the acronym SMET. The main purpose of introducing it was to enhance critical learning power and to get an advantage in the job market in comparison to those who didn't get exposure to STEM. It was first used in the field of engineering for the revolution in technology, such as the bulb, automobiles, etc.

As technology and engineering are the higher-level fields and incorporating them at a school level is quite a challenge. At this level it is required that along with the integration of all four fields in STEM and then Art (STEAM), a curriculum should also include; Evaluations that are more process-based than product-based; Teaching techniques to generate social constructivist and inquiry-based activities; inclusion of digital and tech aided methods like involving robotics augmented project-based learning. STEAM education can achieve a variety of outcomes, including the enhancement, development and improvement of 21st century skills. Although fostering love and interest for a variety of fields STEAM brings a creative element to learning while it's happening but still there are some limitations too and those can be stated as it consumes time, is costly, different curriculum is required, it is difficult to understand without training, and multiple resources are needed. (Kanadlı, 2019). It is believed that the Arts incorporated into STEM cause creativity, problem-solving capability, and build critical thinking ability. Through this approach, new kinds of questions and their diverse answers are coming forward. It makes a child developed while considering the required links in transition from school education and higher education. It fosters some practices like simulation, problem solving, and metacognition. The arts in education

concepts promotes the creative and artistic side of the students thinking which facilitate them to pursue their career in arts field.

STEAM provides a learner with new experiences and opportunities to explore and survive in a diverse world like through imagery and photography, science in schools can be incorporated by teaching optics, biomolecules etc and through films making and movie clips manipulation desktop tech- tool can be used in class. Traditional teaching styles are not helpful in making children capable of problem solving. STEAM will help to eliminate these obstacles. The traditional teaching methods only promotes the limited learning focused on books whereas the modern teaching methods which includes ICTs in education and STEM education promotes the creative side of the students learning process which facilitate students as well as teachers.

The student-centred classrooms cause the engagement of learners, which leads to the learners' autonomy, interest, and inclusion of all learners. During the research, researchers discovered that one of the limitations to STEAM education is that a teacher does not understand what the term "Arts" means. They mostly incorporate any fine arts activity, starting with music and dance, which is not delivering the purpose and is diluting the real concept. The teacher must deliver the same concept through a different approach, like any art activity that further emphasises the topic or content (Park, 2021). Furthermore, the teacher needs to understand that the art education is actually a field which facilitate us to get a good understanding of arts education concepts and practical approaches, theoretical concepts and practice as well.

Although it seems like easy incorporating STEAM into teaching is a strategy that promotes innovation for various other countries, Pakistan has faced certain challenges and limitations in its application. The education system is not fully prepared for its incorporation. Hence, teachers are facing difficulties in several schools, especially public schools. It was observed that there was a lack of infrastructure (laboratories, technology labs, and other resources) which play crucial rule in STEAM teaching. The training of young graduates to handle and use the existing to optimum level should be included in the practice. The presence of some governmental policies, good educational infrastructure, and a curriculum can help in the successful implication of STEAM in Pakistani schools (Hali, Aslam, Zhang, & Saleem, 2020). This is the only way to work on the implementation of STEM education in the Pakistan education context.

This research was conducted for the application of STEAM in Karachi's schools. After data collection, it was inferred that teachers should have first knowledge of what STEAM is, then there should be proper training for the teachers to incorporate the targeted pedagogy in schools. STEAM in classrooms is seen as the future of our generation. STEAM helps a learner think outside the box, which is an important ability in the 21st century (Hammad & khan, 2021).

Another study discusses the inclusion of STEAM concepts in the curriculum, rather than just in the classroom. The addition of all five components to the curricula can meet the growing demand for innovative ideas and talents. For example, STEAM action research as conducted for Slum Schools in Islamabad includes all the five phases of identifying problems in the community,

resolving them through the making and incorporating of STEAM-based lesson plans, and its post survey. After that research it was reported that learners were able to solve their community problems on their own. They were able to apply newly acquired skills and knowledge to the practical problems and challenges they faced. It was only because of the STEAM projects that incorporated skills in them. (Kiyani, Haider, & Javed, 2020)

According to Capraro, Capraro, and Helfeldt (2016), STEAM education can significantly enhance critical thinking skills in elementary school students. Their study found that students who participated in a STEAM program demonstrated significant improvements in their critical thinking abilities compared to those who did not. In a study by Khalid and Ahmad (2019), it was found that STEAM education can promote creativity, innovation, and problem-solving skills among students. The study suggested that the integration of STEAM education in the curriculum can lead to an increased interest in STEM fields and better employment prospects for students. Furthermore, the teacher could create the unique course outline in order to teach the basic concepts of the STEM education in the school, college and university level in the higher education by considering the need of the students as well. It's really important to work on need analysis and knowledge gap. There is the need to work on the development of the unique course outline for STEM education as well.

Furthermore, a study by Lee, Kim, and Kim (2020) found that the integration of STEAM education in the curriculum can help students to develop their communication and collaboration skills, which are essential components of critical thinking. A study by Khalid, Gul, and Bashir (2018) found that the integration of STEAM education in elementary classrooms in Pakistan can enhance students' problem-solving and critical thinking skills. The study also suggested that STEAM education can promote creativity and innovation among students. In another study by Siddiqui and Ahmad (2019), it was found that the integration of STEAM education in the curriculum of primary schools in Pakistan can help students to develop their problem-solving and critical thinking skills. The study suggested that the use of STEAM frameworks can create a dynamic learning environment that engages students and promotes the development of these skills. Additionally, a study by Khan and Raza (2020) found that the integration of STEAM education in the curriculum of elementary schools in Pakistan can promote the development of critical thinking and problem-solving skills among students. The study suggested that STEAM education can enhance students' creativity, innovation, and communication skills.

The research studies suggest that the integration of STEAM education in elementary classrooms can foster a dynamic learning environment that promotes critical thinking and problem-solving skills. Both international and local studies have found that STEAM education can enhance students' creativity, innovation, communication, and collaboration skills, which are essential for success in the 21st century workforce. Further research is needed to explore the specific ways in which STEAM education can be effectively integrated into elementary school curricula in both local and international contexts to enhance critical thinking skills.

3. Methodology

3.1 Setting

My action research was conducted in a small private sector school, "ABC Academy" which is in Federal-B area; one of the most densely populated areas of Karachi. My target audience were the learners of Grade 7 which were 20 in number. The course was taught in correspondence to the National Curriculum using the Sindh Textbook of Science and Sindh Textbook of Mathematics. The faculty were experienced and supportive and parents were involved in supporting learners in their homework. The Zeal Academy is a two-story building and the class I taught was on the 2nd floor. However, the classroom dynamics consisted of a traditional setting of tables and chairs. The classrooms were small and did not have the capacity to accommodate and allow for any group activities and no proper connection for using multimedia. The school has a reasonable computer lab consisting of 10-12 PCs, but there was no science laboratory for carrying out scientific experiments and there was no proper play area but only a small open ground.

3.2 Action Research Cycles

a. Reconnaissance

To identify a particular problem to conduct research on, I went to a school named the Zeal Academy and observed several lessons in Science and Mathematics for class 7. I gathered data through field notes, reflections, and discussions with my mentor and critical friend. During my observations, I came across some major issues the learners were facing in learning.

- Mostly learners in the class were engaged, as they were very responsive and raised their hands when participating in the class. They got excited when they had the activity of solving questions on the board.
- Learners gain interest when provided with a challenge. A few learners were very quick at answering mental Math questions and remained quiet and sat free while others completed their tasks. Other learner wasted their time in talking as they didn't have other tasks to do.
- When an interesting topic of Science was taught through a simple reading pedagogy, learners were yawning in the class and were blank when asked questions about the topic after reading.
- Back benchers find Science classes as their free period in which they can draw sketches as the teacher talks more in the class and they get a lot of unnoticed gaps. They also disturbed other learners and play with their stationary.
- During Science classes the knowledge was limited to textbooks, in the topic of germination of seeds learners were only having long reading and had no experiment. Later when they had a hand-on activity they had a lot of questions and smiles on their faces which showed how fascinated they were to do germination themselves.

- A few of the learners have the habit of asking questions in class. They have that curiosity to ask why for everything. Sometimes this makes the teacher annoyed, as a result the teacher ignored them and asks them to sit silently instead of answering or engaging them.
- I was intrigued by the responses of some learners when they connected the classroom activity with their childhood memories. This refined their ability to reflect critically and build connections.
- The learners were mixing the concept of algebra with rounding off, which shows that the previous concepts are not clear, and learners have many misconceptions.

After multiple observations, I figured out that the learners were lacking something that would keep them backward in this rapidly developing world, and the reason was traditional teaching methods. Looking at the capability of learners to work and their enthusiasm, it was establishing that experiencing technology and hands-on activities can polish their talents and develop their skills. In addition, to explore more and to collect some more concrete evidence, I decided to co-teach with a Science teacher. As Science and Mathematics are my focus areas, I acted as a supporter in the classroom and helped learners solve their misconceptions about the topic of electrons and shells. The learners in the class were highly active and responsive, which shows that they possess sharp cognitive skills. There was a learner who asked some questions during the copy work but was stopped by the teacher. This shows that the completion of work is more important than the clear understanding of a concept. When the learners were provided with strings to make shells and beats to show electrons, the learners got excited and started working efficiently. They started to help each other during work and were happy to do activities. It seems like they were waiting for an activity-based classroom. After this activity, the teacher asked learners to write answers to the questions in their notebooks. Some learners tried to answer in their own words, which I believe is an achievement, however the teacher stopped that individual and forced them to copy from the textbook. It felt like learners express themselves more and understand concepts better when allowed to work with manipulatives and have freedom of expression. This is a common misunderstanding that they have to be controlled all the time. During my reconnaissance, I identified that learners felt considerable difficulty in understanding the concepts in traditional teaching and that gave rise to errors. The issue was that the teaching was based on a teacher-centre approach, whereas a constructivist classroom environment was missing. During observation, I had short conversations with learners in which I asked questions like: which activity interests them most? Which is their favourite class and why? What they like to learn in a classroom and what difficulties they faced? Through this, I tried to learn about their needs and about their learning styles, which I could cater to during my research. I looked through the available literature and came up with the idea of incorporating STEAM education to make them competent. After considering the structure of schools, the standards of the curriculum, and the background of learners, I made an action plan to incorporate STEAM education, knowing that the school context

was different from the literature I found. In my action research, I hope to expose learners to experiential learning, which is a critical need in the twenty-first century.

3.3 AR Cycle 1

Cycle one was based on a total of six lessons. Four lessons are from the science subject, and two are from the mathematics subject. The duration of each lesson varied between 35 and 45 minutes, but some lessons lasted an hour as well. In science, a domain of chemistry was covered, and the topics were isotopes and their uses, chemical bonding, and chemical formulas. On the other hand, two mathematics lessons were delivered in the same class on exponents and profit and loss. All the lessons were prepared with the inclusion of a minimum of three elements of STEAM. Secondly, multiple videos and online tasks were provided, which needed internet access and a device to attempt those tasks individually. Hands-on and mind-on activities were embedded in each lesson. Moreover, a list of resources was asked by the learners to bring to each class, such as UHU, computer papers, scissors, and proper stationary. Learners must identify after every day which component of STEAM is used in the lesson and what its purpose is. They must establish links between each component and write reflections.

3.3.1 Implementation of the plans

- In lesson 1, to incorporate this new approach, a brief introduction of each component of STEAM was provided to the learners. The first step was to give insight about the integration of STEAM and highlight the importance and benefits that would help them learn more effectively without judging or criticizing the methods and approaches through which they were previously learning. Since this is a new concept, I needed to present all the components of STEAM first so that I could include it more extensively in the classroom. Moving on, the development phase of the class in which learners became engineers and created their cubes of isotopes by writing their understanding of the reading. Whereas some of the learners said, "it seems more like an art class." As it was new for them to do in class, apart from making diagrams in their notebooks. Learners were very careful and focused when joining and folding the sides of the cube, as proper measurement is required for a perfect look. Learners found it challenging to read from the book and comprehend themselves, although the reading was limited to one page. Due to the lack of reading habits, the learners were unable to comprehend, and as a result, the outcome was not achieved. The class went on, but no time was left for an explanation of the content. Furthermore, HW was provided to learners to write reflections and summarize their learning on a pallet link. As learners were not aware of this website, I made a tutorial for their guide.
- Lesson 2 was the continuation of the same topic. The learners were unable to perform the task on Padlet as the link was not forwarded to them by their teacher. However, they remembered the task and were keen to attempt to give me motivation to proceed. I heard

learners talking about STEAM with their peers and were discussing their experience of creating cubes and reading about isotopes. The explanation of the content using the formative assessment strategy of questions and answers grabs learners' attention and enhances their understanding of the concept. The learners were able to write answers on their own in the concept cartoon. Now the learners were reading as the explanation was simpler and with cartoon characters. Some learners have an interest in comics, so they enjoyed the task more. The learners were thinking and building connections with their daily lives. They were working in pairs and then discussed their answers in small groups.

- Lesson 3 was based on chemical bonding. First, I used technology to show learners a video about bonds and how they form. The good part was that every learner was much focused and was watching the video. They did raise questions, which were then answered by me. Learners were happy to see an animated video for learning a concept, as they had never seen this approach in class before. I was happy that they took a keen interest in the video and asked questions, but on the other hand, I faced some difficulties too. I didn't find any sockets in the class to connect to. No multimedia was there, so I bought my laptop, but unfortunately, there was no place to put it so that it would be visible to all. But I managed it somehow and the class went on. The purpose of the video was served, which was to my benefit. Secondly, there was a ball activity in which different coloured balls were provided to the learners with symbols of elements written on them. The learners must see those symbols, think about their valence shell and their valency, and lastly, find a pair with whom they can make a chemical bond. To get stable in their elements, they were roaming around the class purposefully, finding the pair for themselves, asking everyone about their valence and looking for a suitable element partner. I was amazed that different chemical bonds came up that I also didn't think of. They were so engaged in that activity and were actively doing it. The class wasn't disciplined, sitting quietly, but they learned in the chaos. The main motive was learning, and that occurred. Learners not only learn the new concept, but they remember it, and every learner actively participated in the class. Moreover, a homework task was also given for the reinforcement of the topic. It was to find different elements from the periodic table and find their suitable elements with whom they could bond. They can choose any element and make as many bonds as they can in their copy.
- Lesson 4 was on the topic of chemical formulas. The lesson was initiated by the story, which included the concept of covalent and ionic bonds. The learners were able to identify the theme and the motive of that story. After that, I explain on board using flash cards the difference between compound molecules and elements through on-going questions and answers. The learners were raising questions to clear up misconceptions. A few learners came on board to write the difference as well. Secondly, the learners were given autonomy to make their own pairs for the activity. They were excited as the charge was given to them so that they could become future leaders and take decisions for themselves. The activity

was to cut out the elements from the list and arrange them to make chemical bonds. Besides, they have to stick that on another sheet and differentiate between molecules, compounds, and elements' formulas. Furthermore, the learners learned collaboratively and were deeply engaged in the process. Learners also work on jam boards as homework and write their reflections about the learning in class and which areas stand out for them. The learners started working as a whole group, then in pairs, and then moved towards individual tasks. They were learning and supporting each other, debating about the concepts, and the most amazing part was when a learner critiqued their formation of bonds and was trying to make them in a new pattern. On the other hand, there was a learner who was connecting the formula with chemical bonds, which shows that the learners were learning.

- Lesson 5 was about mathematics based on the topic of exponents. Now that learners are quite familiar with the incorporation of STEAM, they were excited to study mathematics from a different lens. The learners were provided with some scientific facts that have values written in exponents. The learners in the group of four discussed the similarities between all the scientific facts about the earth. They came up with the response that all the facts have some connections in respect of their number of patterns. Through this, the topic exponent was connected to scientific studies. The learners then understand the mathematical solving of exponents. They identified the benefits of it. Furthermore, they solved a puzzle by solving the sums of exponents. The hands-on activity engaged learners throughout the class, and they were solving each sum to find the right puzzle. After that, as a homework task, the learners were asked to solve a quiz on Kahoot and share their reflections in the next class. Their reflections demonstrated critical understanding and in-depth thought on the subject.
- Lesson 6 was on the profit and loss topic. To begin with, the learners were divided into two large groups and were provided with materials like cloth, utensils, Jewelry and some stationary. They were also provided with the money as small chits. The learners divide their roles as different professions among them to trade with other groups. The condition was to sell all the items within the given time and earn as much money as possible. While trading, they negotiated with the money. They applied multiple strategies to sell all their items. To do this, they plan strategically and cooperatively. Moreover, the topic of profit and loss was introduced to learners, and formulas were taught by me. The learners then solve the sums in their textbooks using the formulas. Finally, the learners created their own problems, reflecting on the first activity, and then applied the formula to solve these problems. The learners had hands-on experience and connected the topic of mathematics to daily life.

3.3.2. Analysis

Success Indicators	**Unsatisfactory Results**

-The learners' work on padlet, jam board, and online quizzes showed their familiarity with the technology to some extent, which was a major barrier for them at the start. -Half of the learners started building connections between the classroom learning and their daily lives, which is evident from their classroom participation and worksheets. -Ten percent of the learners started to reflect critically, which can be seen through their reflections on padlet. -A few of the learners started to solve their problems and become self-directed learners, which can be shown through their extra efforts and worksheets. -Learners have experienced fewer misconceptions when starting learning with STEAM and doing activities in peer and group settings, as evident from their own written reflections.	-Technology was only used as a tool for assessment and was not incorporated into the lessons in the development phase to enhance the conceptual understanding of learners. -One of the major components of STEAM, which is engineering, is missing in most of the lessons that can help to make learners critical learners. -There is a lack of group tasks and inquiry-based assignments to foster decision-making and problem-solving skills among learners. -Learners were unable to connect mathematical understanding with science, and the bar was very low in linking scientific knowledge to mathematics.

3.3.3 Rationale

It is shown from the results that improvements have been made and the objective of enhancing conceptual understanding and creating a constructivist classroom has been achieved up to 35 percent. However, there are many areas that need improvement to achieve the objective and get a better result. In order to raise the bar, I decided to make improvisations and plan lessons for cycle 2.

3.4 AR Cycle 2

Cycle 2 was based on two lessons. One lesson was for mathematics and the other was for science. These lessons were made by doing amendments in pedagogy. In cycle 2, the focus was to use technology to develop an understanding and scaffold the concept. Secondly, using hands-on methods to embed engineering skills in learners.

3.4.1 *Implementation of plans*

Lesson 1 of Cycle 2 was about science, which was based on the topic of the transformation of energy. This topic lasts for two units. The learners were asked to write about what they knew about energy on the jam board link provided to them. Before class, 50 percent of the learners wrote answers on the jam board. The learners went out of the class and were asked to write down the forms of energy they could identify from the environment. After five minutes, when the learners came back, they observed very critically. Learners discussed how energy can be converted after discussing the different types of energy. To explain the law of energy to the learners, I divided the learners into five groups. Instead of making their own groups, I gave them the charge of selecting their own groups because they must work in their groups for one week. Moreover, the learners were provided with the task of creating a model to show the transformation of energy. They were guided to use any available video or research to make their model. A rubric was also provided for this, so that they are aware of what they are expected to do. The learners were excited to work and create models as they were wearing the hats of engineers to explore the science concepts. However, they were allowed to work either in the class or outdoors. They can use their free periods as well to complete the task. In the second class, after two days, the learners came up with amazing creative models. Some showed the transformation of energy through the making of a plastic bottle car and connecting it with rubber bands. Likewise, one group used potatoes to convert energy to light energy. There was one group that used wires and sockets to show the conversion of energy. There was one learner who said, "I will never forget the topic energy now," while the other said, "I wish only this chapter would come on the exam." I was overwhelmed by the responses. The learners worked hard, took responsibility for their learning, and this gave them a life-long learning experience.

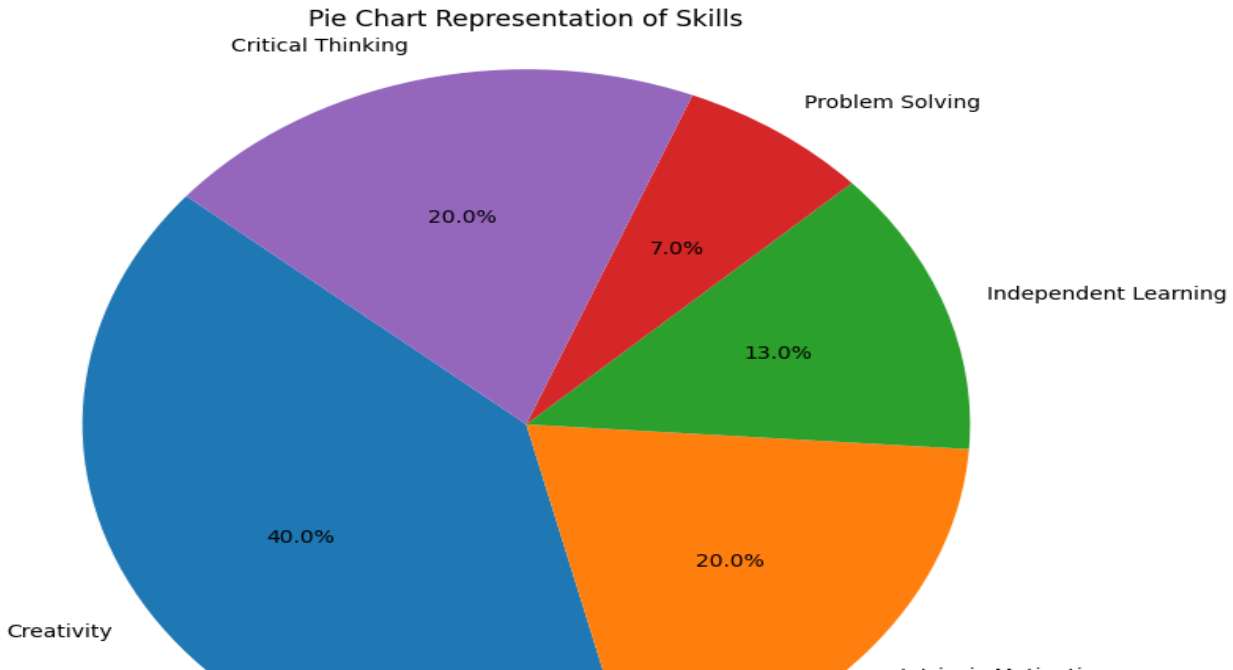
The second lesson for cycle 2 was about mathematics. As this subject required more attention and development of a concept, However, to incorporate technology into the development of mathematical concepts, I asked the cooperating teacher to facilitate with me. To initiate the topic, the learners were divided into groups of four. They were provided with ice cream sticks of different sizes through which they had to make triangles. Each group made different triangles according to the provided sticks. The learners then describe the properties of their triangles. They were encouraged to give angles as well. Some groups guessed the angles, and some used the protector to measure their triangles. After that, to scaffold a concept, I used 3 bug sticks and formed different types of congruent triangles on the board to show them the difference. There were two laptops in the class, so I divided the class into two groups. One was led by me and the other by the cooperating teacher. The learners were provided an opportunity to learn with simulations. In PHET simulations, learners change values and explore more about triangles. They were amazed by the application and were enjoying using it. When the video on math antics was played, the learners interacted with the video, and this cleared some misconceptions that could have been raised on the topic. Lastly, the learners solved the questions from their textbooks. I was glad to see that learners were solving the sums independently.

3.4.2 *Data Analysis*

Success Indicator	Areas for Improvement
1. Creating models of science in groups promotes cooperative learning and is evidence of learners performing higher-order tasks. Collaborative learning cause exchange of ideas and promotes critical thinking and gives opportunity to learners to engage in group discussions. (Gokhale, 2005) 2. Using simulations in mathematics provides most of the learners with a deeper understanding of the concept as well as makes them techno-friendly individuals, which is the need of the 21st century. 3. The creative models and tasks performed on PHET show the effectiveness of teaching and the active involvement of learners in the classroom. 4. More than half of the learners enjoyed learning with a STEAM approach, as they have written in their reflections. One of the learners says, "I want to learn math and science more as it is now exciting and does not need memorization."	1. More collaborative activities are required to develop team-building and decision-making skills. 2. Some learners need higher-order tasks to become competent and to think creatively. 3. Science and mathematics require more activities to enhance critical thinking skills to a greater extent. 4. Exposure to technology in the understanding of science and mathematics concepts is still needed to make learners independent to a higher extent. **5.** Activities such as robotics and abacus are required to improve mental mathematics and create connections with scientific knowledge.

4. Results and Discussion

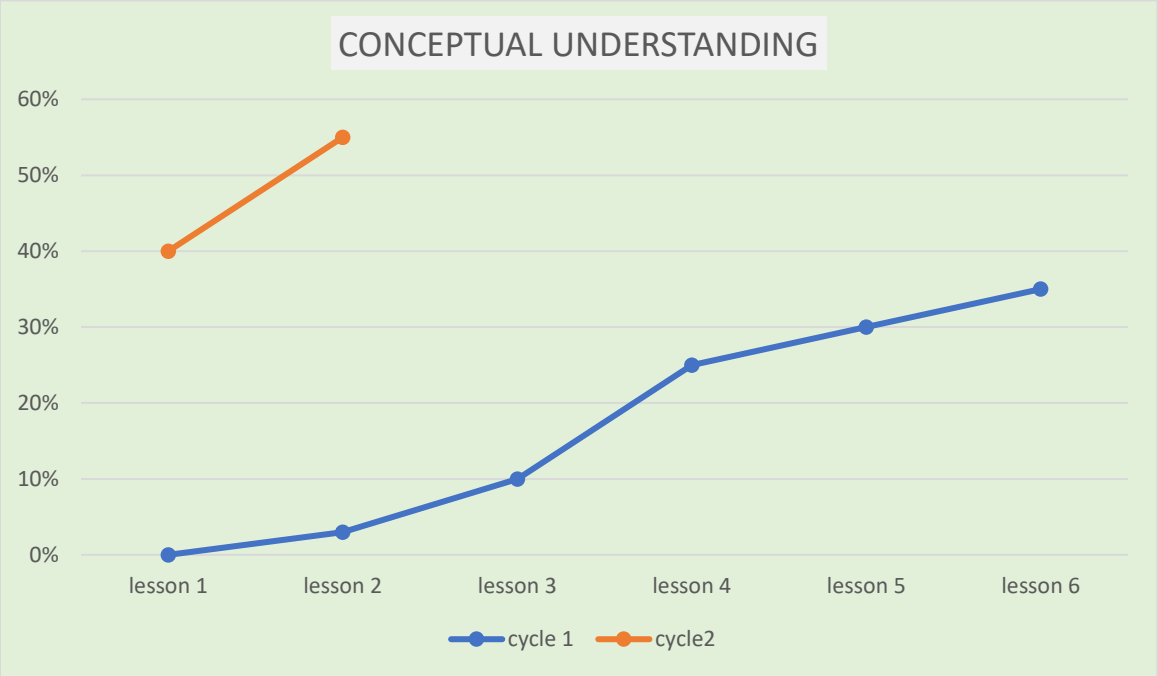
Figure 1



Interpretation

According to the pie chart in Figure 1, the results indicate that 40% of the learners develop creativity in them because of STEAM education. 20% of the learners develop intrinsic motivation in them and become critical thinkers. 13% of them became independent learners and worked on their own. 7% of them solve their daily life problems.

Figure 2



In cycle 1 (Figure 2), it was observed that conceptual understanding after lesson 1 was 0%, but after further lessons it gradually increased to 3%, then 10%, then 25%, 30%, and after the 6th lesson it increased to 35%.

In cycle 1, the results were not fully obtained, so two more lessons in cycle 2 were delivered (Figure 2). It was observed that conceptual understanding did increase by 40% in lesson 1 and by 55% in lesson 2.

4.1 Limitations

- There was a lack of resources, such as laboratories to perform experiments in science.
- lack of multimedia and technological equipment for learners to use the STEAM approach in developing conceptual learning.
- The curriculum standards were not according to the STEAM curriculum.
- Learners demonstrate a lack of reading and comprehension skills, so it was difficult to build from scratch.
- Misconceptions about prior knowledge led to difficulties in building on new knowledge.
- The traditional classroom seating arrangement hampered group activities.

5. Conclusion

It was aimed to create a constructivist classroom through the incorporation of STEAM education, which was not achieved to a greater extent because of several limitations, but it did have an impact on learners' lives. 55% of the learners built conceptual understanding and they did try to build connections between the concepts taught and their daily life problems. The learners got bored in a teacher-centred class, but after having a student-centred class, intrinsic motivation was generated among them. They began to enjoy subjects that they had previously avoided. STEAM contributes to the development of different 21st century skills like decision-making, creativity, critical thinking, and teamwork. According to Barkatsas & Bertram (2016), 21st century skills are those skills which prepare learners to be creative, productive, technology-friendly, and challenge-acceptors, which are important for living in the 21st century. Moreover, if the limitations are overcome in the future, STEAM will show its effect to a much greater extent, and this experiential learning can become lifelong for the learners.

6. Recommendations

According to the results of this study or research Some suggestions are as follow:

- Encourage STEAM education from an early age to develop a learner's critical thinking and problem-solving skills.
- STEAM education is to be included not only in primary schools, but also in elementary and secondary schools.
- Teachers are expected to incorporate STEAM education into their practise to make the class constructivist and for the lifelong learning of learners.
- Resources for incorporating STEAM education need to be provided as it is the greatest limitation in the path of STEAM education.
- Educational programmes and teacher training must be organised to include STEAM in a proper and professional manner.
- Awareness is necessary, and for that, seminars and conferences are required to be organised to get most people aware of STEAM education.

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