DOI: 10.34056/aujef.1464605

Development of Students' Critical Thinking Skills with STEM Activities in Early Childhood Science Education[1]

Erken Çocukluk Döneminde Fen Eğitiminde STEM Etkinlikleriyle Öğrencilerin Eleştirel Düşünme Becerilerinin Geliştirilmesi[1]

Vesile UYULAN[2], Serkan ASLAN[3]

Article Type[4]: Research Article

Application Date: 03.04.2024 **Accepted Date:** 20.07.2024

To Cite This Article: Uyulan, V., & Aslan, S. (2024). Development of students' critical thinking skills with STEM activities in early childhood science education. *Anadolu University Journal of Education Faculty (AUJEF), 8*(3), 971-999.

ABSTRACT: This research examines how design-based STEM (Science, Technology, Engineering, and Mathematics) activities in early childhood affect the development of critical thinking skills in preschool children aged 60-72 months. The research was conducted using an action research design. The participants of the study were determined according to the purposeful sampling method. The researcher's participants consist of 15 children attending preschool education. In the study, the Critical Thinking Skill Rubric was used as a data collection tool. With this scoring key, the students' weekly work based on STEM activities was evaluated and their developments were monitored. The study was conducted with the implementation of 8 STEM scenarios. The data of the research were scored by two different scorers. Descriptive statistics were used in the analysis of the data. In the first week, it was determined that critical thinking skills were insufficient, but a significant improvement was observed in these skills during the application process. The research results show that the students enjoyed the STEM applications, their interest levels increased, and the problems experienced during the activity process decreased. Various suggestions have been presented based on the research results.

Keywords: Design-based STEM, early childhood education, science education, critical thinking, action research

[1] This study is derived from a part of the master's thesis conducted by the first author under the supervision of the second author.
[2] Master's Degree, vesileuyulan3216@hotmail.com, ORCID: 0000-0003-1330-505X
[3] Assoc. Prof. Dr., Süleyman Demirel University, Faculty of Education, serkanaslan@sdu.edu.tr, ORCID: 0000-0001-8515-4233 (Corresponding author)
[4] Ethics committee approval: E-87432956-050.99-413434

ÖZ: Bu araştırma, erken çocukluk döneminde tasarım tabanlı STEM (Fen, Teknoloji, Mühendislik ve Matematik) etkinliklerinin okul öncesi eğitime devam eden 60-72 aylık çocukların eleştirel düşünme becerilerini geliştirmeye nasıl etki ettiğini incelemektedir. Araştırma, eylem araştırması deseni kullanılarak yürütülmüştür. Araştırmanın katılımcıları amaçlı örnekleme yöntemine göre belirlenmiştir. Araştırmacının katımıcılarını okul öncesi eğitimde öğrenim gören 15 çocuk oluşturmaktadır. Araştırmada veri toplama aracı olarak, Eleştirel Düşünme Becerisi Dereceli Puanlama Anahtarı kullanılmıştır. Bu puanlama anahtarıyla öğrencilerin, STEM etkinliklerine dayalı olarak haftalık yapmış oldukları çalışmaları değerlendirilmiş ve gelişmeleri izlenmiştir. Araştırma, 8 STEM senaryosunun uygulanmasıyla gerçekleştirilmiştir. Araştırmanın verileri, iki farklı puanlayıcı tarafından puanlanmıştır. Verilerin analizinde betimsel istatistik kullanılmıştır. İlk haftada eleştirel düşünme becerilerinin yetersiz olduğu belirlenmiş ancak uygulama sürecinde bu becerilerde belirgin bir gelişme gözlemlenmiştir. Araştırma sonuçları, öğrencilerin STEM uygulamalarından keyif aldıklarını, ilgi düzeylerinin arttığını ve etkinlik sürecinde yaşanan sorunların azaldığını göstermektedir. Araştırma sonuçlarına dayanarak çeşitli öneriler sunulmuştur.

Anahtar sözcükler: Tasarım tabanlı STEM, erken çocukluk eğitimi, fen eğitimi, eleştirel düşünme, eylem araştırması

1. INTRODUCTION

In today's rapidly changing world, science, technology, engineering, and mathematics (STEM) fields form the foundation of the education system, considering the need for individuals' ability to solve complex problems. Especially in early childhood, the foundations of people's cognitive and emotional development are laid. The opportunities offered by STEM education in this period, where children acquire basic skills and their interest in learning develops, can help develop critical thinking skills early on. This implies the need to conduct STEM activities within the scope of science education.

The preschool period is an important process that will help children develop basic scientific concepts and areas of interest. In this age group, science education can help improve children's interactions with nature and their environment and enhance their science thinking skills (Buldu, 2018). Science education in the preschool period is an excellent opportunity to attract children's interest and encourage them to understand natural phenomena. Moreover, children who receive science education at an early age can develop their interest and achievements in science later on (Uludağ & Erkan, 2020; Yıldız & Zengin, 2023). Preschool science education should be conducted with an interactive and discovery-based approach. Children at this age learn by observing nature, conducting experiments, and asking questions (Buldu, 2018). For example, children can learn about the properties of water through simple experiments or learn about the life cycle of plants by growing plants in the garden. These types of activities can increase children's interest and desire to learn and allow them to experience science tangibly.

Science education in the preschool period can significantly contribute to the cognitive, emotional, and social development of children. As stated by Akintemi and Oduolowu (2021), Bahar and Aksüt (2020) and Santos (2017) science activities can help children develop skills such as observation, problem-solving, and critical thinking. It is also emphasized that introducing science concepts at an early age can increase children's interest in science and support their interest in science-related careers in the future (Campbell & Howitt, 2023; Yıldız & Zengin, 2023). In this context, it can be understood that science education in the preschool period can positively contribute to the cognitive and emotional development of children. Therefore, teaching practices should be implemented using contemporary approaches and models in science education. In this way, students can be more effectively equipped with these skills. Today, we see that activities based on STEM education are being implemented in science education. This approach can increase students' interest in the natural sciences by emphasizing practical applications in science education and interdisciplinary connections and can support their orientation towards science-related careers in the future.

STEM (Science, Technology, Engineering, and Mathematics) is an educational approach that includes the disciplines of science, technology, engineering, and mathematics. These disciplines are becoming increasingly important today and play a critical role in developing skills to meet the needs of the business world and society (Fleer, 2013). The implementation of STEM education in the preschool period allows children to develop their basic cognitive, emotional, and social skills. This period is a critical stage where learning is fastest and basic habits and interests are shaped (Smeddy, 2023). Therefore, the implementation of STEM education in this period can lay a solid foundation for children's future success.

STEM education in the preschool period should be carried out with an interactive and discovery-based approach. During this period, children learn about the world by exploring and experimenting with the objects around them (Yore et al., 2014). Therefore, STEM activities can be an important tool for arousing children's curiosity and directing them to science thinking processes. For example, children can understand basic physics concepts by examining simple machines or discover natural sciences by cultivating plants (Moomaw, 2024). These kinds of activities allow children to improve their problem-solving skills and make their discoveries.

STEM activities in the preschool period contribute to the development of children's fundamental skills such as critical thinking, problem-solving, collaboration, and communication (Clements & Sarama, 2011). In this regard, it can be stated that STEM activities in preschool education have critical importance. These skills are important not only for academic success but also for dealing with challenges they will encounter throughout their lives. Moreover, STEM activities can encourage children to a lifelong learning journey by supporting their science thinking processes and curiosity (Eshach & Fried, 2016). Therefore, regular implementation of STEM activities in the preschool period can provide significant contributions to children's cognitive and emotional development. It can also improve students' higher-order thinking skills in the preschool period as mentioned above. These skills include critical thinking.

Critical thinking is a cognitive process that includes the ability to question, analyze, synthesize, and evaluate information (Facione, 2011). This process allows individuals to develop a critical attitude towards information and logically evaluate their thoughts. Individuals who think critically approach information not superficially, but in depth and in an analytical way. Moreover, critical thinking is also associated with the ability to understand and clearly express different views (Ennis, 1987). The preschool period is a critical period in which children develop their basic cognitive and emotional skills. Developing critical thinking skills during this period can help children develop a questioning attitude towards information and strengthen their problem-solving skills (Göktürk, 2015). Acquiring critical thinking skills in the preschool period can contribute to children's future success in education and their ability to solve complex problems more effectively. There are effective strategies for developing critical thinking skills in the preschool period. For example, it is important to encourage their thinking processes by providing opportunities for children to ask and answer questions (Lipman, 2003). Also, children's problem-solving and logical thinking skills can be encouraged through games and interactive activities (Bartolini-Bussi & Mariotti, 2008). These types of activities allow children to strengthen their critical thinking processes by practising.

Mater et al. (2011) state that STEM-focused activities play an important role in developing children's critical thinking skills. Especially, the process of encountering problems related to science, technology, engineering, and mathematics and finding solutions to these problems can strengthen children's critical thinking skills. For example, while conducting a science experiment or solving a math puzzle, children can develop their critical thinking skills by forming hypotheses, analyzing data, and evaluating their results. Moreover, as stated by Çetin and Demircan (2020) and Pekbay (2023), activities offered with STEM education in the preschool period can help children not only learn science and mathematical concepts but also understand how they can use these concepts in their daily lives. This allows students to develop these skills more effectively by associating critical thinking skills with real-world applications.

Science education is closely related to STEM disciplines and there is a strong interaction between these disciplines. STEM applications in science education in the preschool period can provide important opportunities for students to develop their science thinking processes and critical thinking skills (Hebebci & Usta, 2022). STEM activities provide children with the opportunity to explore science topics, conduct experiments, and solve problems. These activities allow children to experience science concepts tangibly and strengthen their critical thinking skills (Topsakal, Altun Yalçın & Çakır, 2022). For example, while conducting a science experiment, children may encounter problems and use their critical thinking abilities to solve these problems. Critical thinking can be considered as a fundamental component of STEM activities. Because science education provides students with the opportunity to apply science thinking processes, which can help develop their critical thinking skills (Bybee, 2013). Students are required to use their critical thinking skills while following steps such as making observations, collecting data, and drawing conclusions during science experiments. Also, when students are allowed to use their problem-solving and analytical thinking skills during STEM activities, critical thinking skills can naturally develop (Gopnik, 2018). Developing critical thinking skills with STEM applications in science education in the preschool period can make significant contributions to children's cognitive and emotional development. These activities stimulate children's curiosity and strengthen their problem-solving skills, encouraging them to think critically (Baharin, Kamarudin & Manaf, 2018). Also, learning through STEM activities provides active participation for students, which contributes to the strengthening of critical thinking skills (Cunningham & Carlsen, 2014).

Research conducted in Turkey on STEM reveals that STEM-focused applications enhance the skills of pre-school students such as problem-solving, science process, visual-spatial abilities, reasoning, critical thinking, creative thinking and increase their intrinsic motivation levels (Abanoz, 2020; Asığığan, 2019; Bal, 2018; Başaran, 2018; Behram, 2019; Çilengir Gültekin, 2019; Güldemir & Çınar, 2021; Kavak, 2020; Öcal, 2018; Öztürk, 2020; Şimşek, 2022; Ünal, 2019; Üret, 2019). However, when the literature in Turkey is reviewed, it has been determined that there are few studies aimed at improving critical thinking skills through STEM activities in the pre-school period (Şimşek, 2022). This situation indicates a significant gap in the literature. Therefore, it has been decided to conduct such a study.

One of the researchers, who also serves as a preschool teacher, during his duty, observed that sufficient attention was not given to STEM activities in preschool education institutions around him and there was a lack of activities supporting 21st-century skills for children. This observation was confirmed in a study conducted by Aslan and Uyulan (2023); the study concluded that teachers do not apply STEM activities in science education. These results show that the STEM approach in science education is not adequately adopted in early childhood. The preschool period is a critical period that forms the basis of children's cognitive and emotional development. During this period, the application of STEM activities through science education can play a critical role in developing students' critical thinking skills. In addition, today's rapidly changing technological and scientific developments require students to have strong foundations in STEM fields. It is important to support these foundations with the development of critical thinking skills; because critical thinking is a fundamental skill that includes skills such as evaluating information, problem-solving, and creative thinking. In this context, the importance of research focusing on science education in the preschool period to introduce children to STEM activities at an early age and to develop their critical thinking skills emerges. Such research can help preschool teachers and educational institutions improve their practices in this area and form a strong foundation for children's future academic and professional success. In this context, the researcher's experiences and observations emphasize the need for more research on developing STEM activities and critical thinking skills in early childhood. This research can make a significant contribution both in practical education and in terms of educational policies and can help encourage strategic changes in the field of preschool education.

Based on the research results, if it is found that STEM activities contribute to the development of students' critical thinking skills, these results will guide preschool teachers. In this case, teachers will use contemporary learning-teaching models more effectively and will be able to raise children with the knowledge and skills required by their age. Similarly, if it is concluded that STEM activities contribute to the development of critical thinking skills, these research results will provide feedback to faculty members in teacher training programs. This feedback may encourage the planning of STEM education as a separate course in early childhood teacher training programs and may provide faculty members with information and opportunities to plan activities based on 21st-century skills. As a result, this research will be an important step towards developing critical thinking skills with STEM activities in early childhood. Gaining these skills at an early age can form a solid foundation for children's future academic and professional success and can contribute positively to the development of education systems. The research aims to develop the critical thinking skills of children aged 60-72 months in science education in the preschool period with STEM activities based on action research. In line with this goal, the following question has been sought:

"*How do STEM activities during early childhood contribute to changes and improvements in students' critical thinking skills?*"

2. METHOD

2.1. Research Design

This study aims to investigate the development of students' critical thinking skills through STEM activities in early childhood education, aligning with the principles of action research within qualitative research paradigms. Action research involves collaboratively addressing real-world issues or improving situations with participants. Researchers work together with participants to understand the roots of a problem, plan interventions, and evaluate their effects (Reason & Bradbury, 2008). Another definition of action research describes it as a method where researchers work alongside participants as part of a societal change process (Stringer, 2014). Within the spectrum of action research, participatory action research was chosen for this study. Participatory action research involves the researcher actively participating in implementing the research design aimed at addressing issues, subjects, or programmes for change and development (Mills, 2014). In this conducted research, based on the research problem, the researcher preferred participatory action research because she conducted the research at the school where she serves and tried to develop students' critical thinking skills.

2.2. Study Group

Action research is often carried out with consciously selected samples with small groups in terms of numbers (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz & Demirel, 2016, p. 267). In this study, the purposive sampling method was chosen because it was considered appropriate for the problem situation, and in-depth information was desired. Purposive sampling involves including elements that can provide the necessary information the best (Özdemir, 2016). In purposive sampling, the researcher selects the samples with the thought of which elements will represent the study universe most accurately (Babbie, 2007). Also, purposive sampling offers the researcher the opportunity to conduct in-depth and detailed research on a predetermined small group (Güçlü, 2020, p. 90). In the research, convenience sampling, which is one of the types of purposive sampling, was also utilized. Convenience sampling is expressed as the researcher collecting data from volunteers that can be easily accessed (Mills & Gay, 2019). In this study, purposeful and appropriate sampling methods were used due to working with individuals appropriate to the purpose and problem situation of the research, saving time, and the researcher conducting the application with the children in the school where he/she works. The observation that the group where the research was conducted lacked critical thinking skills and this situation was also expressed by teachers has been the reason for researching this group. In addition, the critical thinking skills of the students were measured using the measurement tool developed within the scope of the research, and it was determined that the student's critical thinking skills were at a low level. In light of this information, the study group of the research consists of 15 students aged 60-72 months who receive preschool education in a province of the Central Anatolia Region in the 2022-2023 academic year. The information on the children participating in the research is given in Table 1.

Table 1. *Information on the Study Group*

Student Code	Gender	Mother Occupation	Father Occupation	Socio-economic level	Mother and Father	Place of residence
S1	M	Homemakers	Imam	Low	Alive	District center
S2	M	Teacher	Teacher	Medium	Alive	District center
S3	M	Teacher	Teacher	Medium	Alive	District center
S4	F	Nurse	Engineer	High	Alive	District center
S5	F	Homemakers	Teacher	Medium	Alive	District center
S6	M	Teacher	Civil servants	Medium	Alive	District center
S7	F	Civil servants	Civil servants	Medium	Alive	District center
S8	F	Homemakers	Farmer	Medium	Alive	District center
S9	M	Homemakers	Teacher	Medium	Alive	District center
S10	M	Homemakers	Farmer	Low	Alive	District center
S11	M	Teacher	School principals	Medium	Alive	District center
S12	F	Nurse	Teacher	Medium	Alive	District center
S13	F	Teacher	School principals	Medium	Alive	District center
S14	M	Civil servants	Teacher	Medium	Alive	District center
S15	F	Teacher	Teacher	Medium	Alive	District center

Upon reviewing Table 1, it is observed that the study group consists of 7 female and 8 male students. In terms of the occupation of the mothers, 5 are homemakers, 6 are teachers, 2 are nurses, and 2 are civil servants. As for the fathers, 7 are teachers, 2 are civil servants, 2 are farmers, 2 are school principals, 1 is an engineer, and 1 is an imam. Regarding the socio-economic status of the families, it has been determined that 1 family has a high level, 2 families have a low level, and 12 families have a medium level. When considering the survival status of the parents, it is observed that all of the children's parents are alive. In terms of the settlement area where the students reside, it is found that all students live in the district centre.

2.3. Data Collection Tool

Two types of data collection tools were used in the study. These are:

2.3.1. *Critical Thinking Skills Rubric*

In this research, a rubric was used to determine whether the critical thinking skills of students participating in STEM activities in preschool education were developed. The rubric is an assessment tool used in both process and product evaluation, presenting detailed performance indicators and levels (Şahin, 2019). According to the literature, there are two different types of rubrics: holistic and analytic. While a holistic rubric evaluates the measured abilities, skills, or task elements as a whole (Yaşar, 2018), an analytic rubric is preferred when there are different components of performance (Bıkmaz-Bilgen, 2019). In this study, an analytic rubric was used to describe students' performances in more detail. The main reason for this is the division of critical thinking into sub-skills and the goal of determining whether students have acquired these sub-skills.

The Critical Thinking Skills Rubric consists of 6 dimensions (explaining, interpreting, predicting, establishing cause and effect relationships, inferring, and summarising skills), (Dilekli, 2019; Facione, 2011), and each item is scored from a minimum of 1 to a maximum of 3 points. Thus, the lowest score that can be obtained from the rubric is 6, and the highest score is 18. During the development process of the rubric, the opinions of 10 different experts were obtained, and the content validity index was examined. The value of this index was determined to be .80 (Yeşilyurt & Çapraz, 2018). In addition, analyses such as the Pearson correlation coefficient, Kendall concordance coefficient, and Cronbach's Alpha coefficient were conducted to determine the reliability of the scores (Kutlu, Doğan & Karakaya, 2023). Within the scope of the research, STEM activities were applied to a total of 54 students, and three observers filled out the rubric during these activities to evaluate the students' critical thinking skills. When selecting scorers, criteria such as having high seniority and having completed postgraduate studies in their fields were considered. Pearson correlation analysis, Cronbach's alpha reliability coefficients, and Kendall concordance coefficients were examined in the data analysis obtained from three scorers, and a moderate to high level of correlation coefficient was obtained. The Cronbach's Alpha coefficient for the rubric for critical thinking skills was found to be .72, indicating a high level of agreement among scorers (Can, 2019). The scores obtained; It has been interpreted as low between 6-10, medium between 11-14, and high between 15-18. The critical thinking skills rubric was scored by the teachers, considering the activities carried out by the students within the scope of the STEM activities and the students' explanations about the activities.

2.3.2. *Photographs*

In the scope of the research, photographs were used to reflect the products and processes of the actions carried out based on the STEM teaching approach. Choen, Manion, and Morrison (2017) stated that photographs can support different data collection tools. In this research, photographs of the products made by students were taken to demonstrate the development of critical thinking skills.

2.4. Action Plan and Data Collection

The research was conducted during the academic year 2022-2023, from March 6, 2023, to May 2, 2023. Necessary permissions were obtained from the Provincial Directorate of National Education and the school administration to carry out the research. STEM activity plans were implemented for one day a week, totalling 5 activity hours. An 8-week STEM activity plan was prepared, with each week focusing on a different theme. The prepared activity plans were shared with the classroom teacher where the implementation would take place, and their opinions were taken into account. To ensure that the plans served the purposes of the research, three expert opinions and two preschool teachers' opinions were obtained to develop the plans, and the final versions were determined. Within the parameters of the research, a pilot application involved implementing the STEM activity plan for a week in three different classrooms. After the implementation, the observed deficiencies were corrected. Within the study, an action plan lasting 8 weeks was created, considering the preschool curriculum achievements and indicators. The action plan is presented in Table 2 below.

Table 2. *Action Plan Implemented in the Research*

Week	Activity	Relation with Science	Relation with Technology	Relation with Engineering	Relation with Mathematics
March 6	Let's Make a Water Mill	Energy	Renewable Energy Technologies	Product Design	Sequencing
March 13	Building a Bridge	Weight-Balance	Technological Developments	Product Design	Calculation
March 20	My Rocket in Space	Space	Technological Developments	Product Design	Length Measurement
March 27	Our Body	Systems	Technological Developments	Model Design	Measurement
April 3	Periscope Under the Sea	Light, Reflection	Underwater Technologies	Product Design	Measurement, Calculation
April 10	What's a Catapul?	Energy Transformation	Technological Developments	Product Design	Length Measurement
April 24	Insect Hotel	Life of Organisms	Technological Developments	Product Development	Mathematical Expressions
May 2	Crazy Robots	Robotics, Coding	Technological Developments	Product Development	Classification

In this study, STEM activities planned for 8 weeks were implemented. As seen in Table 2, on March 6, 2023, the "Let's Build a Water Mill" activity; on March 13, 2023, the "Building a Bridge" activity; on March 20, 2023, the "My Rocket in Space" activity; on March 27, 2023, the "Our Body" activity; on April 3, 2023, the "Periscope Under the Sea" activity; on April 10, 2023, the "What's a Catapul?" activity; on April 24, 2023, the "Insect Hotel" activity; and on May 2, 2023, the "Crazy Robots" activity were implemented. In this study, the researcher carried out pre-planned STEM activities, and evaluations were based on the results of the implementation and the advice of experts. Eight different STEM activities were implemented in the study, and data were collected through these activities. The weekly action plans are explained below:

2.4.1. *Week Let's Make a Water Mill STEM Activity*

The activity focused on the topic of the force of water in the field of science, aiming to develop skills related to focusing on objects/situations/events to be observed. In the field of mathematics, it aimed to develop skills in comparison, sequencing, and "comparing the properties of objects and beings." In the field of technology, experience with Web 2.0 tools was provided. In the field of engineering, skills in problem-solving, drawing, and design creation were aimed at being developed. The activity included reading the book "Su Dedikleri Var Ya" (They Call It Water) and then having discussions about the value and application of water. Then, a water-carrying game was played, and after the game, animations related to the topic were watched. Following the animations, the students completed their worksheets. Finally, the students designed water mills using cardboard cups, egg cartons, and popsicle sticks.

2.4.2. *Week My Rocket in Space STEM Activity*

The activity focused on the topic of space and planets in the field of science, aiming to develop the skill of "observing objects and beings." In the field of mathematics, it addressed skills in comparison, sequencing, and "comparing the properties of objects and beings." In the field of technology, a technological experience was provided using the MERGE Explorer application. In the field of engineering, skills in problem-solving, drawing, and design creation were aimed at being developed. The activity included playing math-related games after reading the book "Astronaut" (Astronot). Then, animations and cartoons related to space and rockets were watched to provide detailed information about the topic. Design drawings were made for rocket designs, and balloons, toilet paper rolls, playdough, and plastic bottles were used in the design process. 3. Week: Building a Bridge STEM Activity: The activity focused on the topic of weight and balance in the field of science, aiming to develop the skill of "applying instructions related to spatial position." In the field of mathematics, it addressed skills in comparison, sequencing, and "comparing the properties of objects and beings." In the field of technology, a technological experience was provided using the MERGE Explorer application. In the field of engineering, skills in problem-solving, drawing, design creation, and engineering concepts were aimed at being developed. The activity included playing finger games and reading the book "Bize Bir Köprü Lazım" (We Need a Bridge). Then, math-related games were played, and pictures related to bridges and their features were shown. Measurements were made using a balance scale, and comparisons were made between objects that were heavy and light. Design drawings were made for bridge designs, and materials such as wooden sticks, scissors, tape, glue, playdough, plastic bottles, and white cardboard were used in the design process.

2.4.3. *Week Bridge Building STEM Activity*

The activity application addressed the concepts of weight and balance in the field of science, aiming to implement the learning outcomes related to 'applying spatial instructions.' In the field of mathematics, the focus was on developing comparison and ordering skills, targeting the learning outcomes of 'compares the properties of objects and entities.' In the realm of technology, a technological experience was provided using the MERGE Explorer application. In the field of engineering, problem-solving, drawing, design creation, and engineering concepts were addressed, aiming to enhance students' skills in these areas. At the beginning of the activity, finger games were played, and the book titled 'We Need a Bridge' was read. Following the story, a game of knocking down balls was played to address mathematical outcomes. Subsequently, pictures related to the topic were shown, and discussions with students about bridges and their characteristics were conducted. Measurements of different objects were made using a balance scale, and comparisons were made between objects that were heavy and light. A design for the activity application was drawn, and students were encouraged to develop bridge designs. During this process, materials such as popsicle sticks, scissors, tape, glue, playdough, plastic bottles, and white cardboard were utilised.

2.4.4. *Week Our Body STEM Activity*

The activity focused on the topic of our body and systems in the field of science, aiming to develop students' skills in "observing objects and beings." In the field of mathematics, it included skills in comparison and sequencing to support the achievement of "grouping objects or beings according to their properties." In the field of technology, the Wordwall Web 2.0 tool was used to provide students with a technological experience. In the field of engineering, skills in recognising engineering, drawing, and design creation were provided. The activity started with a "skeleton dance" to capture the children's interest. After reading the book "Vücudumuz" (Our Body), math-related games followed. After the game, materials were collected to create a skeleton model in the garden, and games were played with the skeleton model. Various cartoons about our bodies were watched, and activity pages related to rhythmic numbers were completed. Then, students moved on to the product creation phase, where they developed skeleton designs using materials such as different-sized plastic bottles, toilet paper, glue, and cotton swabs.

2.4.5. *Week Periscope Under the Sea STEM Activity*

The activity focused on the topic of the reflection of light in the field of science, aiming to develop students' skills in "paying attention to objects, situations, and events." The field of mathematics, included skills in classification and sequencing to support the achievement of "ordering objects or beings according to their properties." In the field of technology integration, technology was used for research and to benefit from videos related to problem situations, utilising a Web 2.0 tool. In the field of engineering, it supported problem-solving and design creation skills. The activity began with reading the book "Denizler Ne Kadar Derin" (How Deep Are the Seas), followed by a submarine drama. The meaning of the periscope was discussed with the children, and their guesses were drawn on paper. Then, educational videos to give more details about the periscope followed by a game involving both shallow and deep concepts. The children were given pictures of periscopes to arrange in order and were encouraged to design and transform their imagined periscopes into products. At the end of the activity, assessors used scales to allow children to evaluate themselves and their designs.

2.4.6. *Week What's a Catapul? STEM Activity*

The activity focused on the topic of energy transformation in the field of science, aiming to develop students' skills in "generating solutions to problem situations." In the field of mathematics, it included counting and sequencing skills to support the achievement of "counting objects." In the field of technology integration, technology was used for research and to benefit from videos related to problem situations. In the field of engineering, it supported problem-solving and design creation skills. The activity began with asking children to guess what a "Catapult" could be and to draw their guesses. Then, an educational video was shown to provide information about the topic. At the end of the video, a game related to the topic was played, and children were given Catapul puzzles to complete. After gaining enough knowledge about the Catapul, students were asked to design their Catapuls and transform their designs into products. After the products were created, students were asked to draw what they learned on paper based on their initial guesses about the Catapul, and comparisons were made with these drawings.

2.4.7. *Week The Insect Hotel STEM Activity*

The activity was designed to enhance students' skills in observing objects or entities within the domain of life sciences, focusing specifically on living organisms and their habitats. In the realm of mathematics, it encompassed the development of classification and measurement skills through grouping objects or entities according to their properties. Within technology integration, the utilisation of technology for research, leveraging videos related to problem scenarios, and employing the Web 2.0 tool Jigsaw Planet were anticipated. In the field of engineering, it aimed to support problem-solving, prototyping, and design creation skills. During the initial phase of the activity, children were seated using the circle technique, and the book "Benek's Light" was read aloud. Following the narrative, children were provided with a worksheet for matching insects, where they were asked to pair insects with similar names. After asking the kids what they thought about magnifying glasses, an explanation of their function followed. A leader was chosen from each group, and these leaders were provided with magnifying glasses to examine insects in the garden. Upon returning to the classroom, children were given both narrow and wide sheets of paper to create grass. Then, various insect images were distributed, and children were instructed to paste them on the grass. After the activity, groups presented their work to each other, describing the insects they observed in the garden. Discussions were facilitated on the habitats, body parts, and characteristics of insects to ensure that students had foundational knowledge, supplemented by educational videos for detailed information. Subsequently, children were guided in designing insect hotels and assisted in placing them in the garden. At regular intervals, visits to the garden were conducted to determine the number of insects present, which were then recorded in tables.

2.4.8. *Week Crazy Robots STEM Activity*

The activity aimed to enhance students' skills in paying attention to objects, situations, or events within the domain of science by addressing the topic of robotics. In the field of mathematics, it included the acquisition of counting and recognition of geometric shapes skills through the objectives of "counting objects" and "recognising geometric shapes." Technology integration envisages leveraging technology for research and utilising videos related to problem scenarios. In the realm of engineering, it supported problem-solving, drawing, and design creation skills. During the initial phase of the activity, the storybook titled "Strawberry-Picking Robot" was read, followed by distributing worksheets featuring robot drawings to the students. After discussing robots with the students, each child was given a blank sheet of paper to design a robot using the geometric shapes they had learned. To reinforce the knowledge, students engaged in interactive games involving robots, listened to songs, and watched educational videos. Once the necessary preliminary learning was achieved, students were tasked with designing their imagined robots, and materials were distributed to groups to facilitate the construction of their robots. After the completion of the products, drama, symmetry, and water texture studies were conducted for assessment purposes.

2.5. Data Analysis

In the research, descriptive statistics were utilised by employing a rating scale key for data analysis, aiming to convert the obtained data into meaningful numerical values and gain insight into whether students' critical thinking skills were being developed or not (Taşpınar, 2017). In this context, the arithmetic mean was used for describing the collected data, which is the most commonly used measure of central tendency obtained by summing all values and dividing by the number of participants

(Kilmen, 2020). Two different scorers independently evaluated the students' work in the STEM activities during the implementation of the research. Scorers observed students' work within the class during STEM activities, took notes, asked questions, and elicited explanations, and summaries regarding how students performed their work considering the dimensions of the rating scale key. Thus, each scorer independently scored the rating scale key. The average of these scores was calculated and presented in the findings section to comprehensively evaluate the results of the research.

2.6. Validity and Reliability in the Research

Validity and reliability evaluations in qualitative research require a different approach than in quantitative research. Validity and reliability in qualitative research are based on credibility, transferability, dependability, and confirmability criteria (Erlandson, Harris, Skipper & Allen, 1993; cited in Yıldırım & Şimşek, 2018). In this research, to enhance credibility, the researcher interacted with the participants for 8 weeks and consulted with academic experts in the field regarding the use of scales, making necessary adjustments. The purposive sampling method was preferred to enhance transferability (Sığrı, 2018). Moreover, the purposive sampling method, one of the appropriate sampling methods, was used to determine the study group. To ensure dependability, it is important to eliminate personal judgements in the evaluation and interpretation of data. Therefore, in this study, two observers other than the researcher scored the scales (Turan & Özer Özkan, 2019). To ensure confirmability, the researcher's role, data collection process, and data analysis stages should be clearly explained (Sığrı, 2018). In this research, the position of the research in the process was clearly stated, and the data collection process and data analysis were explained in detail.

2.7. Role of the Researcher

In this study, the researchers have actively collaborated throughout the process from defining the problem to reporting the results. This process has allowed them to combine their knowledge and skills, achieving a broader perspective and a deeper understanding. The first researcher has taken on the task of conducting the research. This researcher, who has completed a course called "Qualitative Research Methods" in her postgraduate education, also has a series of publications based on qualitative research. This experience and knowledge base have made the first researcher a competent expert in qualitative research. This researcher, who is responsible for the design and implementation of the research, has managed the entire process with honesty and meticulousness, thus ensuring that the research progresses by scientific standards. The second researcher is an expert who conducts courses in postgraduate education based on qualitative research. He also has a large number of studies on the qualitative research model. In other words, this researcher also has deep knowledge and experience in his field. The knowledge and skills of both researchers have contributed to the process and outcomes of the research, ensuring that the study is robust and comprehensive. The second researcher has played a significant role, especially in the analysis process. He has managed the analysis and interpretation of the data, thus ensuring the reliability and validity of the research findings. He has also taken on a significant role in the design and reporting processes of the research. This has helped maintain a high standard of quality at every stage of the research process.

3. FINDINGS

In this section of the study, the findings regarding the development of students' critical thinking skills through STEM activities implemented over 8 weeks in early childhood have been presented weekly with tables, and the obtained data have been evaluated and interpreted.

3.1. First Week

The rubric scores that students received for the development of their critical thinking skills for the first week are presented in Table 3.

Table 3. *Findings Related To Rubric Raw Scores And Averages Provided By Evaluators For The Development Of Students in The First Week*

Student	1. Student		2. Student		3. Student		4. Student		5. Student		6. Student		7. Student		8. Student	
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Total Score	7	6	7	7	8	10	9	9	8	7	10	9	8	8	10	11
Average Score	6,5		7		9		9		7,5		9,5		8		10,5	
Student	**9. Student**		**10. Student**		**11. Student**		**12. Student**		**13. Student**		**14. Student**		**15. Student**			
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**		
Total Score	6	8	9	8	10	10	8	9	9	11	6	6	7	8		
Average Score	7		8,5		10		8,5		10		6		7,5			
Overall Average	8,3															

Upon examining Table 3, it can be observed that the average scores given by the evaluators for the first student are $\overline{X}$=6.5, for the second student are $\overline{X}$=7, for the third student are $\overline{X}$=9, for the fourth student are $\overline{X}$=9, for the fifth student are $\overline{X}$=7.5, for the sixth student are $\overline{X}$=9.5, for the seventh student are $\overline{X}$=8, for the eighth student are $\overline{X}$=10.5, for the ninth student are $\overline{X}$=7, for the tenth student are $\overline{X}$=8.5, for the eleventh student are $\overline{X}$=10, for the twelfth student are $\overline{X}$=8.5, for the thirteenth student are $\overline{X}$=10, for the fourteenth student are $\overline{X}$=6, and for the fifteenth student are $\overline{X}$=7.5. It is also noted that the overall average of all the activities for the first week is $\overline{X}$= 8.3. Based on this outcome, it can be inferred that students' critical thinking skills are at a relatively low level for the first week.

Photo 1. *First Week STEM Activity Implementation Photos*

3.2. Second Week

Table 4 displays the students' scores for honing their critical thinking abilities from the rubric in the second week.

Table 4. *Findings Regarding The Raw Scores And Averages Provided By Evaluators For The Development Of Students' Skills in The Second Week*

Student	1. Student		2. Student		3. Student		4. Student		5. Student		6. Student		7. Student		8. Student	
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Total Score	8	8	9	8	9	10	11	10	9	9	10	10	9	8	12	12
Average Score	8		8,5		9,5		10,5		9		10		8,5		12	
Student	**9. Student**		**10. Student**		**11. Student**		**12. Student**		**13. Student**		**14. Student**		**15. Student**			
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**		
Total Score	7	9	10	9	12	11	9	11	10	12	8	7	8	10		
Average Score	8		9,5		11,5		10		11		7,5		9			
Overall Average	9,5															

Upon examining Table 4, the average scores given by evaluators for each student in the second week are as follows: the average score for the first student is $\overline{X}$=8, for the second student, is $\overline{X}$=8.5, for the third student is $\overline{X}$=9.5, for the fourth student is $\overline{X}$=10.5, for the fifth student is $\overline{X}$=9, for the sixth student is $\overline{X}$=10, for the seventh student is $\overline{X}$=8.5, for the eighth student is $\overline{X}$=12, for the ninth student is $\overline{X}$=8, for the tenth student is $\overline{X}$=9.5, for the eleventh student is $\overline{X}$=11.5, for the twelfth student is $\overline{X}$=10, for the thirteenth student is $\overline{X}$=11, and for the fourteenth student is $\overline{X}$=7.5, and for the fifteenth student is

$\overline{X}$=9. It is observed that the overall average score for all activities in the second week is also $\overline{X}$=9.5. Based on these findings, it can be concluded that the student's level of critical thinking skills is low.

Photo 2. *Second Week STEM Activity Implementation Photos*

3.3.Third Week

Table 5 displays the results of the student's performance on the rubric for the third week of developing their critical thinking abilities.

Table 5. *Findings Related To The Raw Scores From The Rubric And Averages Provided By Evaluators For The Development Of Students in The Third Week*

Student	**1. Student**		**2. Student**		**3. Student**		**4. Student**		**5. Student**		**6. Student**		**7. Student**		**8. Student**	
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Total Score	9	8	8	7	8	9	12	10	10	11	9	8	10	8	12	10
Average Score	8,5		7,5		8,5		11		10,5		8,5		9		11	
Student	**9. Student**		**10. Student**		**11. Student**		**12. Student**		**13. Student**		**14. Student**		**15. Student**			
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**		
Total Score	8	9	10	11	12	12	9	9	10	10	7	8	9	8		
Average Score	8,5		10,5		12		9		10		7,5		8,5			
Overall Average	9,36															

Upon examination of Table 5, it can be observed that the average scores given by evaluators for the first student is $\overline{X}$=8.5, for the second student is $\overline{X}$=7.5, for the third student is $\overline{X}$=8.5, for the fourth student is $\overline{X}$=11, for the fifth student is $\overline{X}$=10.5, for the sixth student is $\overline{X}$=8.5, for the seventh student is $\overline{X}$=9, for the eighth student is $\overline{X}$=11, for the ninth student is $\overline{X}$=8.5, for the tenth student is $\overline{X}$=10.5, for the eleventh student is $\overline{X}$=12, for the twelfth student is $\overline{X}$=9, for the thirteenth student is $\overline{X}$=10, for the fourteenth student is $\overline{X}$=7.5, and for the fifteenth student is $\overline{X}$=8.5. The overall average score for all activities in the third week is $\overline{X}$=9.36. Based on these findings, it can be concluded that the student's level of critical thinking skills is low. It was observed that there was a partial decrease in the third week. This could be due to this week's STEM event being heavily focused on mathematics and engineering.

Photo 3. *Fourth Week STEM Activity Implementation Photos*

3.4. Fourth Week

Table 6 below shows the results of the student's performance on the rubric for the fourth week of developing their critical thinking abilities.

Table 6. *Findings Regarding The Raw Scores And Averages Given By Evaluators For The Development Of Students in The Fourth Week*

Student	**1.Student**		**2.Student**		**3.Student**		**4.Student**		**5.Student**		**6.Student**		**7.Student**		**8.Student**	
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Total Score	10	9	11	10	11	12	12	12	11	11	10	12	10	9	14	13
Average Score	8,5		10,5		11,5		12		11		11		9,5		13,5	
Student	**9.Student**		**10.Student**		**11.Student**		**12.Student**		**13.Student**		**14.Student**		**15.Student**			
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**		
Total Score	9	11	12	10	14	12	10	11	12	14	10	9	9	13		
Average Score	10		11		11		10,5		13		9,5		11			
Overall Average	10,9															

Upon examination of Table 6, it is observed that the average scores given by evaluators for the first student are $\overline{X}$=8.5, for the second student is $\overline{X}$=10.5, for the third student is $\overline{X}$=11.5, for the fourth student is $\overline{X}$=12, for the fifth student is $\overline{X}$=11, for the sixth student is $\overline{X}$=11, for the seventh student is $\overline{X}$=9.5, for the eighth student is $\overline{X}$=13.5, for the ninth student is $\overline{X}$=10, for the tenth student is $\overline{X}$=11, for the eleventh student is $\overline{X}$=11, for the twelfth student is $\overline{X}$=10.5, for the thirteenth student is $\overline{X}$=13, for the fourteenth student is $\overline{X}$=9.5, and for the fifteenth student is $\overline{X}$=11. It is also evident that the overall average of all activities for the fourth week is $\overline{X}$=10.9. Based on these findings, it can be concluded that the student's level of critical thinking skills is medium.

Photo 4. *Fourth Week STEM Activity Implementation Photos*

3.5. Fifth Week

Table 7 displays the results of the student's critical thinking test scores for the fifth week.

Table 7. *Findings Regarding The Raw Scores And Averages Provided By Evaluators For Students' Development in The Fifth Week*

Student	**1.Student**		**2.Student**		**3.Student**		**4.Student**		**5.Student**		**6.Student**		**7.Student**		**8.Student**	
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Total Score	11	12	12	12	12	13	13	12	13	10	11	12	12	10	14	14
Average Score	11,5		12		12,5		12,5		11,5		11,5		11		14	
Student	**9.Student**		**10.Student**		**11.Student**		**12.Student**		**13.Student**		**14.Student**		**15.Student**			
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**		
Total Score	11	12	13	12	15	14	12	13	14	16	12	11	12	13		
Average Score	11,5		12,5		14,5		12,5		15		11,5		12,5			
Overall Average	12,40															

Upon examining Table 7, it is observed that the average scores given by evaluators for the first student is $\overline{X}$=11.5, for the second student is $\overline{X}$=12, for the third student is $\overline{X}$=12.5, for the fourth student is $\overline{X}$=12.5, for the fifth student is $\overline{X}$=11.5, for the sixth student is $\overline{X}$=11.5, for the seventh student is $\overline{X}$=11, for the eighth student is $\overline{X}$=14, for the ninth student is $\overline{X}$=11.5, for the tenth student is $\overline{X}$=12.5, for the eleventh student is $\overline{X}$=14.5, for the twelfth student is $\overline{X}$=12.5, for the thirteenth student is $\overline{X}$=15, for the fourteenth student is $\overline{X}$=11.5, and for the fifteenth student is $\overline{X}$=12.5. It is also noted that the overall average for all activities in the fifth week is $\overline{X}$=12.4. Based on these findings, it can be concluded that the student's level of critical thinking skills is medium.

Photo 5. *Fifth Week STEM Activity Implementation Photos*

3.6. Sixth Week

Table 8 presents the raw scores and averages of the evaluations provided by the assessors regarding the development of student's critical thinking skills for the sixth week.

Table 8. *Findings Regarding The Raw Scores And Averages Given By The Assessors For Students' Development in The Sixth Week*

Student	1.Student		2.Student		3.Student		4.Student		5.Student		6.Student		7.Student		8.Student	
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Total Score	12	14	12	13	14	13	14	12	12	9	12	12	11	12	16	13
Average Score	13		12,5		13,5		13		10,5		12		11,5		14,5	
Student	**9.Student**		**10.Student**		**11.Student**		**12.Student**		**13.Student**		**14.Student**		**15.Student**			
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**		
Total Score	13	14	15	14	15	15	13	13	16	17	13	14	14	15		
Average Score	13,5		14,5		15		13		16,5		13,5		14,5			
Overall Average	13,40															

Upon examining Table 8, it is observed that the average scores given by the assessors for the first student is $\overline{X}$=13, for the second student is $\overline{X}$=12.5, for the third student is $\overline{X}$=13.5, for the fourth student is $\overline{X}$=13, for the fifth student is $\overline{X}$=10.5, for the sixth student is $\overline{X}$=12, for the seventh student is $\overline{X}$=11.5, for the eighth student is $\overline{X}$=14.5, for the ninth student is $\overline{X}$=13.5, for the tenth student is $\overline{X}$=14.5, for the eleventh student is $\overline{X}$=15, for the twelfth student is $\overline{X}$=13, for the thirteenth student is $\overline{X}$=16.5, for the fourteenth student is $\overline{X}$=13.5, and for the fifteenth student is $\overline{X}$=14.5. It is observed that the overall average of all the activities in the sixth week is $\overline{X}$=13.4. Based on these findings, it can be concluded that the student's level of critical thinking skills is medium.

Photo 6. *Sixth Week STEM Activity Implementation Photos*

3.7. Seventh Week

Table 9 displays the results of the student's performance on the rubric for the seventh week of developing their critical thinking abilities.

Table 9. *Scores Obtained By Students From The Rubric And Related Averages For The Seventh Week*

Student	1.Student		2.Student		3.Student		4.Student		5.Student		6.Student		7.Student		8.Student	
Evaluator	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Total Score	14	15	14	13	15	15	14	15	13	11	14	11	13	12	18	15
Average Score	14,5		13,5		15		14,5		12		12,5		12,5		16,5	
Student	**9.Student**		**10.Student**		**11.Student**		**12.Student**		**13.Student**		**14.Student**		**15.Student**			
Evaluator	1	2	1	2	1	2	1	2	1	2	1	2	1	2		
Total Score	14	15	14	15	17	16	12	14	17	17	12	14	15	15		
Average Score	14,5		14,5		16,5		13		17		13		15			
Overall Average	14,30															

Upon examination of Table 9, it is observed that the average scores given by the evaluators to the first student are $\overline{X}$=14.5, the second student is $\overline{X}$=13.5, the third student is $\overline{X}$=15, the fourth student is $\overline{X}$=14.5, the fifth student is $\overline{X}$=12, the sixth student is $\overline{X}$=12.5, the seventh student is $\overline{X}$=12.5, the eighth student is $\overline{X}$=16.5, the ninth student is $\overline{X}$=14.5, the tenth student is $\overline{X}$=14.5, the eleventh student is $\overline{X}$=16.5, the twelfth student is $\overline{X}$=13, the thirteenth student is $\overline{X}$=17, the fourteenth student is $\overline{X}$=13, and the fifteenth student is $\overline{X}$=15. It is observed that the overall average of all the studies in the seventh week is $\overline{X}$=14.3. Based on these findings, it can be concluded that the student's level of critical thinking skills is medium.

Photo 7. *Seventh Week STEM Activity Implementation Photos*

3.8. Eighth Week

Table 10 displays the raw scores and averages derived from the rubric that the evaluators provided for the eighth week regarding students' development of critical thinking skills.

Table 10. *Findings Regarding the Raw Scores and Averages of Students' Development as Evaluated by Evaluators for the Eighth Week*

Student	1.Student		2.Student		3.Student		4.Student		5.Student		6. Student		7.Student		8. Student	
Evaluator	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Total Score	16	16	15	14	17	16	18	18	16	14	14	12	13	15	18	18
Average Score	16		14,5		15		18		15		13		14		18	
Student	**9. Student**		**10. Student**		**11. Student**		**12. Student**		**13. Student**		**14. Student**		**15. Student**			
Evaluator	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**		
Total Score	17	17	16	15	18	18	15	17	18	18	16	14	18	18		
Average Score	17		15,5		18		16		18		15		18			
Overall Average	16,06															

Table 10 reveals that the average scores given by evaluators for the first student is $\overline{X}$=16, for the second student is $\overline{X}$=14.5, for the third student is $\overline{X}$=15, for the fourth student is $\overline{X}$=18, for the fifth student is $\overline{X}$=15, for the sixth student is $\overline{X}$=13, for the seventh student is $\overline{X}$=14, for the eighth student is $\overline{X}$=18, for the ninth student is $\overline{X}$=17, for the tenth student is $\overline{X}$=15.5, for the eleventh student is $\overline{X}$=18, for the twelfth student is $\overline{X}$=16, for the thirteenth student is $\overline{X}$=18, for the fourteenth student is $\overline{X}$=15, and for the fifteenth student is $\overline{X}$=15. The overall average for all activities in the eighth week is $\overline{X}$=16.06. Based on this result, it can be inferred that students have a high level of critical thinking skills.

Photo 8. *The STEM Activity Implementation Photos for the Eighth Week*

3.9. Evaluation of All Weeks

The general average of the activities in the first week was $\overline{X}$=8.30, in the second week $\overline{X}$=9.5, in the third week $\overline{X}$=9.36, in the fourth week $\overline{X}$=10.9, in the fifth week $\overline{X}$=12.40, in the sixth week $\overline{X}$=13.40, in the seventh week $\overline{X}$=14.3, and in the eighth week $\overline{X}$=16.06. When all these findings are examined, it is observed that the average increased in the first and second weeks decreased in the third week, and then increased steadily in the subsequent weeks. Based on these results, it can be said that the STEM activities implemented within the framework of action research contribute to the development of students' critical thinking skills.

4. DISCUSSION

In this part of the research, the research results reached in line with the findings presented in the previous section have been discussed within the scope of the literature. This study examined the development of critical thinking skills of students in early childhood through STEM activities. The results of the research show that STEM activities improve students' critical thinking skills, particularly in the sub-dimension of explanation. Critical thinking involves the ability to delve deep into problems, examine them from various angles, and understand and object if necessary, beyond just being a cognitive activity (Aybek, 2010). In this context, it is emphasized that it is important to acquire critical thinking skills at an early age. The sub-dimension of explanation of critical thinking skills includes the ability of students to express their arguments and thoughts (Facione, 1990). In our research, it has been observed that STEM activities provide children with the opportunity to explain and narrate their work, thereby enabling the development of skills such as expressing themselves, clearly expressing their emotions, and speaking in public. In the activities implemented, students were particularly encouraged to present their arguments developed within the framework of STEM activities. In this context, it has been concluded that STEM activities improve the sub-dimension of explanation of critical thinking skills. This result can be considered a significant contribution to the research, especially considering that young children struggle to express themselves clearly and openly. Because developing this skill can positively impact children's future education lives and increase their academic success.

The second sub-dimension of the research shows that STEM activities also improve critical thinking skills, particularly the sub-dimension of interpretation. The interpretation dimension of critical thinking skills includes the process of deeply understanding, analyzing, and examining a situation, event, or information from various perspectives. This skill enables the individual to approach information critically and make explanations and interpretations. Interpretation skill involves analyzing data obtained from various information sources, reaching conclusions logically, making inferences, and making evaluations about their correctness (Ennis, 2011). Especially in the preschool period, critical thinking skills are very important for children. During this period, children are curious, eager to explore, and have a questioning state of mind. Developing critical thinking skills increases children's ability to question, understand, and interpret information. At the same time, it allows children to express their thoughts and understand the world around them more deeply. The result that the sub-skill of interpretation of critical thinking skills is developed with STEM activities is one of the important results of our research. Developing interpretation skills in the preschool period can enable children to approach information more deeply and help them understand the world around them more comprehensively. This can enable children to acquire knowledge based on more solid foundations and be more successful in their future lives. In addition, interpretation skill enables children to analyze a situation and predict possible outcomes. This can enable children to approach the problems they encounter in their daily lives more effectively and solution-oriented. Interpretation skill also enables children to express their ideas clearly and understand the ideas of others. This can enable children to be more successful in their social interactions and contribute more effectively to teamwork. In a study conducted by Asığığan (2019), it was stated that gamified STEM activities had a positive effect on students' critical thinking skills. This supports the result of our research.

In the research, it was found that STEM activities improve the sub-dimension of establishing cause-effect relationships of critical thinking skills. Establishing cause-effect relationships involves the process of students understanding the causes and possible consequences of an event (Dilekli, 2019). In this research, the focus has been on developing this sub-skill of critical thinking by encouraging students to explain the causes of simple events. In early childhood, it is suggested that there may be some difficulties in establishing cause-effect relationships. However, today, with the advancement of science and technology, children are introduced to technology at an early age and have access to various information. For example, through some digital games, children explain the reasons for the situations they encounter, which is observed by teachers. In the research conducted by Şimşek (2022), it was concluded that STEM education improved children's critical thinking skills and enabled students to establish cause-effect relationships. This result supports the result of this research. In addition, the development of the skill of establishing cause-effect relationships can also support problem-solving ability. Individuals who develop problem-solving skills can produce more effective solutions to the problems they encounter in their daily lives, which can increase their reasoning abilities. The development of critical thinking skills in children is expected to increase their ability to solve any problem in their lives. In the development of these skills, it can be stated that engineering skills included in STEM activities make a significant contribution. Engineering skills such as product design, trial and error process, and investigating the cause of incorrect applications can positively support children's ability to establish cause-effect relationships.

In the research, it was found that STEM activities improve the sub-dimension of making inferences of critical thinking skills. With the development of inference skills, it can be stated that children contribute to reaching their unique conclusions with their skills to analyze and evaluate their inferential judgments. Critical thinking skill is a complex process that encompasses individuals' ability to analyze, synthesize, and evaluate information. Inference making, a significant part of this process, enables individuals to draw logical conclusions from existing data. These results demonstrate that STEM activities enhance students' analytical thinking, problem-solving, and logical inference skills. This implies that STEM activities can increase students' cognitive abilities and better prepare them. Therefore, incorporating STEM activities more frequently in preschool education institutions and including them in the curriculum could be an effective way to develop students' critical thinking skills. Capraro and Slough (2013) concluded that STEM project-based learning improved students' high-level thinking skills such as critical and analytical thinking, collaboration, peer communication, and problem-solving skills. The findings obtained from this research show that STEM activities affect critical thinking skills. It can be stated that applications focusing on mathematical skills included in the STEM discipline support children's analytical thinking and inference skills. In these activities, children have been encouraged to make inferences.

Similarly, the effect of STEM activities on critical thinking skills has also been seen in the summarization sub-dimension. Ennis (2011) stated that one of the critical thinking skills is summarizing arguments. Summarization involves individuals expressing the event holistically by reviewing the entire process and establishing a relationship between important points. The activities carried out within the scope of the research have contributed to children's understanding of the relationship between events and performing higher-level mental processes. Therefore, it can be concluded that applied summarization improves students' critical thinking skills. The curiosity, love of discovery, and the tendency to constantly ask questions of preschool children form the basis of critical thinking. In this research, it has been observed that methods such as collaborative learning, research inquiry with family participation, group studies, presentation of discussion environments, and active participation of children in the process improve critical thinking skills. In addition, it has been observed that the active use of Web 2.0 tools improves children's ability to use technology and provides an interactive learning environment.

Looking at the literature, the number of studies on critical thinking skills with STEM activities in early childhood is very limited. In the studies conducted in this field, it has been observed that the study groups are generally primary, and middle school students, teachers, and teacher candidates. Tanın (2021), Alkoç (2020), and Hacıoğlu (2017) concluded in their studies that STEM applications contributed positively to the development of critical thinking skills of teacher candidates. Topsakal (2018) and Tekin's (2020) studies have concluded that STEM activities positively affect the critical thinking skills of primary and middle school students. Based on these study results, it can be stated that STEM activities applied at different levels improve students' critical thinking skills.

The researcher observed that the materials given to the children at the beginning of the process were used only for the purpose. As the research process progressed, it was noticed that children did not get stuck in function, they used a material for different purposes. At the same time, it was seen that the children were only interested in their products in the first activities and they made positive and negative inferences towards the designs of other friends while dealing with the shortcomings of their products as the process progressed and intervened where necessary. Based on this impression, it can be stated that the STEM activities applied within the scope of the research improve children's critical thinking skills. The teacher of the class where the application was made stated, "Even during their free play time, students try to make designs, they constantly try to interpret and explain something. During activity hours, they express their opinions by saying, 'Wouldn't it be better if we did this?' and most importantly, they constantly discover cause-effect relationships between situations." This shows that STEM activities in science education provide students with critical thinking skills and make these skills a part of their lives.

5. CONCLUSION

The findings from the study provide compelling evidence that the integration of STEM (Science, Technology, Engineering, and Mathematics) activities into early childhood science education significantly bolsters students' critical thinking skills. These activities serve as key influencers in shaping students' abilities to analyse information, interpret data, establish cause-and-effect relationships, summarise their findings, explain theories, and evaluate hypotheses. This valuable data shines a spotlight on the pivotal role that STEM activities play in the realm of early childhood education. By creating an environment where students are allowed to apply science and mathematical concepts in a practical setting, we empower them to develop an in-depth understanding of these disciplines. This approach transcends the traditional theoretical learning methods and allows students to grasp these concepts on a practical level as well. It facilitates a more comprehensive understanding of the subject matter and encourages them to engage with the content in a more meaningful way. The implementation of STEM activities in early childhood education plays a crucial role in shaping students' perspectives. It empowers them to perceive and interpret future situations from a multitude of angles. This ability to approach situations from different perspectives is an invaluable skill that will benefit them in countless ways throughout their lives. Moreover, the integration of STEM activities into early childhood curricula can also stimulate the development of problem-solving and creative thinking skills. These skills are not only essential in navigating everyday situations but are also highly sought after in the 21st-century workforce. In the context of these findings, the research underscores the profound importance of STEM education in the early stages of childhood education. By embracing this approach, we can cultivate a generation of individuals equipped with the skills necessary for the 21st century. This strategy has the potential to significantly contribute to the scientific and economic development of countries by nurturing a workforce capable of driving innovation and growth.

6. LIMITATIONS AND RECOMMENDATIONS

Our research has been conducted according to action research, one of the qualitative research designs. Therefore, there is a limitation in terms of generalizing the results of our research. Experimental studies can be conducted to generalize the research. Similarly, conducting studies with more participants can contribute to the generalizability of the research results. The research was conducted over only eight weeks. Conducting studies that cover a longer period will contribute to the literature. Within the scope of the research, only whether one of the high-level thinking skills, critical thinking skill, has developed or not has been examined. Studies can be conducted on whether STEM activities develop the problem-solving skills and creative thinking skills of students who are educated in pre-school.

Declaration of Contribution Rate of Authors

The authors contributed equally to the research.

Disclosure Statement

The authors report there are no competing interests to declare.

REFERENCES

Abanoz, T. (2020). *STEM yaklaşımına uygun fen etkinliklerinin okul öncesi dönem çocuklarının bilimsel süreç becerilerine etkisinin incelenmesi.* Yayımlanmamış doktora tezi. Gazi Üniversitesi, Ankara.

Akintemi, E. O., & Oduolowu, E. A. (2021). Sciencing activities and scientific skills of children at pre-primary level in Nigeria. *International Online Journal of Primary Education (IOJPE), 10*(1), 106-118.

Alkoç, N. (2020). *Okul öncesi öğretmen adaylarının 21. yüzyıl öğrenen becerileri ile eleştirel düşünme eğilimleri arasındaki ilişkinin incelenmesi.* Yayımlanmamış yüksek lisans tezi. Kafkas Üniversitesi, Kars.

Asığğan, İ.S. (2019). *Oyunlaştırılmış STEM uygulamalarının öğrencilerin içsel motivasyon düzeyleri eleştirel düşünme eğilimi ve problem çözme becerisi algıları üzerindeki etkisi.* Yayınlanmamış yüksek lisans tezi. Bahçeşehir Üniversitesi, İstanbul.

Aslan, S. & Uyulan, V. (2023). Erken çocukluk döneminde fen eğitimine yönelik öğretmen görüşlerinin ve uygulamalarının incelenmesi. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi, 66,* 502–543.

Aybek, B. (2010). *Örneklerle düşünme ve eleştirel düşünme.* Nobel Kitapevi.

Babbie, E. (2007). *The basics of social research*. Thomson Higher Education.

Bahar, M. & Aksüt, P. (2020). Investigation on the effects of activity-based science teaching practices in the acquisition of problem solving skills for 5-6 year old pre-school children. *Journal of Turkish Science Education, 17* (1), 22-39.

Baharin, N., Kamarudin, N., & Manaf, U. K. A. (2018). Integrating STEM education approach in enhancing higher order thinking skills. *International Journal of Academic Research in Business and Social Sciences, 8*(7), 810–822.

Bal, E. (2018). *FeTeMM (fen, teknoloji, mühendislik, matematik) etkinliklerinin 48-72 aylık okul öncesi çocuklarının bilimsel süreç ve problem çözme becerilerinin üzerindeki etkisinin incelenmesi.* Yayımlanmamış yüksek lisans tezi. Marmara Üniversitesi, İstanbul.

Bartolini-Bussi, M., & Mariotti, M. A. (2008). Semiotic mediation in the mathematics classroom: artifacts and signs after a Vygotskian perspective. In L.D. English & D. Kirshner (Eds.). *Handbook of international research in mathematics* (pp. 746-783). Routledge.

Başaran, M. (2018). *Okul öncesi eğitimde STEM yaklaşımının uygulanabilirliği (eylem araştırması).* Yayımlanmamış doktora tezi. Gaziantep Üniversitesi, Gaziantep.

Behram, M. (2019). *STEM öğretim yaklaşımının okul öncesi dönemi öğrencilerinin bilimsel süreç becerilerine etkisinin incelenmesi.* Yayımlanmamış yüksek lisans tezi. İstanbul Aydın Üniversitesi, İstanbul.

Bıkmaz-Bilgen, Ö. (2019). Tamamlayıcı ölçme ve değerlendirme teknikleri 1: Performans değerlendirme. N. Doğan (Ed.). *Eğitimde ölçme ve değerlendirme* içinde (s. 181-216). Pegem Akademi Yayıncılık.

Buldu, M. (2018). The effect of science education on the critical thinking skills of preschool children. *International Journal of Education and Research, 6*(3), 11-20.

Büyüköztürk, Ş. Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş. & Demirel, F. (2016). *Bilimsel araştırma yöntemleri.* Pegem Akademi Yayıncılık.

Bybee, R.W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association.

Campbell, C. & Howitt, C. (2023). The place of sicence in the early years. In C. Campbell & C. Howitt (Eds.). *Science in early childhood*. Cambridge University Press

Can, A. (2019). *SPSS ile bilimsel araştırma sürecinde nicel veri analizi*. Pegem Akademi Yayıncılık.

Capraro, R.M. & Slough, S.W. (2013). Why PBL? Why STEM? Why now? An introduction to STEM project based learning. In R.M. Capraro, M.M. Capraro, & J. Morgan (Eds.). *STEM project-based learning: An integrated Science, Technology, Engineering, and Mathematics (STEM) approach* (2nd Edition). (pp. 1-5). Rotterdam.

Clements, D.H., & Sarama, J. (2011). Early childhood mathematics intervention. *Science, 333*(6045), 968-970.

Cohen, L., Manion, L. & Morrison, K. (2017). *Research methods in education.* Routledge.

Cunningham, C.M., & Carlsen, W.S. (2014). Teaching engineering practices. *Science and Children, 52*(1), 42-47.

Çetin, M., & Demircan H.Ö. (2020). STEM education in early childhood. *Inonu University Journal of the Faculty of Education, 21*(1), 102-117. DOI: 10.17679/inuefd.437445

Çilengir-Gültekin, S. (2019). *Okul öncesinde eğitimde drama temelli erken STEM programının bilimsel süreç ve yaratıcı düşünme becerilerine etkisi.* Yayımlanmamış yüksek lisans tezi. Aydın Adnan Menderes Üniversitesi, Aydın.

Dilekli, Y. (2019). *Etkinliklerle düşünme öğretimi*. Pegem Akademi Yayıncılık.

Ennis, R. (2011). *The nature of critical thinking: An outline of ciritical thinking dispositions and abilities*. University of Illinois.

Eshach, H., & Fried, M.N. (2016). Should science be taught in early childhood? *Journal of Science Education and Technology, 25*(4), 553-569.

Facione, P.A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction - executive summary - the delphi report*. The California Academic Press.

Facione, P.A. (2011). *Critical thinking: What it is and why it counts*. Insight Assessment.

Fleer, M. (2013). *Science in early childhood.* Cambridge University Press.

Gopnik, A. (2018). Scientific thinking in young children: Theoretical advances, empirical research, and policy implications. *Science, 359*(6381), 1-8.

Göktürk, G. (2015). Investigating the effects of teaching critical thinking skills with the conceptual change instruction method on students' critical thinking. *Educational Sciences: Theory & Practice, 15*(1), 173-184.

Güçlü, İ. (2020). *Sosyal bilimlerde nicel veri analizi*. Gazi Kitapevi.

Güldemir, S. & Çınar, S. (2021). STEM etkinliklerinin okul öncesi öğrencilerinin yaratıcı düşünmesine etkisi. *Erken Çocukluk Çalışmaları Dergisi. 5(*2), 359–383.

Hacıoğlu, Y. (2017). *Fen, teknoloji, mühendislik ve matematik (STEM) eğitimi temelli etkinliklerin fen bilgisi öğretmen adaylarının eleştirel ve yaratıcı düşünme becerilerine etkisi.* Yayımlanmamış doktora tezi. Gazi Üniversitesi, Ankara.

Hebebci, M. T., & Usta, E. (2022). The effects of integrated STEM education practices on problem solving skills, scientific creativity, and critical thinking dispositions. *Participatory Educational Research, 9*(6), 358-379. https://doi.org/10.17275/per.22.143.9.6

Kavak, Ş. (2020). *STEM öğretim yaklaşımına dayalı etkinliklerin okul öncesi çocukların temel bilimsel süreç becerilerine etkisi.* Yayımlanmamış doktora tezi. Çukurova Üniversitesi, Adana.

Kilmen, S. (2020). *Eğitim araştırmacıları için SPSS uygulamalı istatistik*. Anı Yayıncılık.

Kutlu, Ö., Doğan, C.D. & Karakaya, İ. (2023). *Ölçme ve değerlendirme. Performansa ve portfolyoya dayalı durum belirleme.* Pegem Akademi Yayıncılık.

Lipman, M. (2003). *Thinking in education (2nd ed.).* Cambridge University Press.

Mater, N. R., Haj Hussein, M. J., Salha, S. H., Draidi, F. R., Shaqour, A. Z., Qatanani, N., & Affouneh, S. (2020). The effect of the integration of STEM on critical thinking and technology acceptance model. *Educational Studies*, *48*(5), 642–658. https://doi.org/10.1080/03055698.2020.1793736

Mills, G.E. (2014). *Action research: A guide for the teacher researcher*. Pearson.

Mills, G.E. & Gay, L.R. (2019). *Educational research*. Pearson.

Moomaw, S. (2024). *Teaching STEM in the early years, 2nd edition: activities for ıntegrating science, technology, engineering, and mathematics*. Redleaf Press.

Öcal, S. (2018). *Okul öncesi eğitime devam eden 60-66 ay çocuklarına yönelik geliştirilen STEM programının çocukların bilimsel süreç becerilerine etkisinin incelenmesi*. Yayımlanmamış yüksek lisans tezi. Yıldız Teknik Üniversitesi, İstanbul.

Özdemir, A. (2016). *Yönetim biliminde ileri araştırma yöntemleri ve uygulamalar*. Beta.

Öztürk, Z.D. (2020). *STEM etkinliklerinin okul öncesi öğrencilerin problem çözme becerisine etkisi.* Yayınlanmamış yüksek lisans tezi. Recep Tayyip Erdoğan Üniversitesi, Rize.

Pekbay, C. (2023). A sample STEM activity based on the engineering design process: A study on prospective preschool teachers' views. *Participatory Educational Research, 10*(1), 86-105. http://dx.doi.org/10.17275/per.23.5.10.1

Reason, P., & Bradbury, H. (2008). *The Sage handbook of action research: Participative inquiry and practice*. Sage.

Santos, L. F. (2017). The role of critical thinking in science education. *Journal of Education and Practice*, *8*(20), 160-173.

Sığrı, Ü. (2018). *Nitel araştırma yöntemleri*. Beta Yayınları.

Smeddy, N. (2023). *Early childhood education: preparation in teaching and administration*. Training Learning and Consulting.

Stringer, E. T. (2014). *Action research*. Sage publications.

Şahin, M.G. (2019). Performansa dayalı değerlendirme. B. Çetin (Ed.), *Eğitimde ölçme ve değerlendirme* içinde (s. 215-268). Anı Yayıncılık.

Şimşek, V. (2022). *STEM öğretim yaklaşımı uygulamalarının okul öncesi dönemde yaratıcılık ve eleştirel düşünme becerisine etkisi.* Yayımlanmamış yüksek lisans tezi. Alanya Alaaddin Keykubat Üniversitesi, Antalya.

Tanın, K. (2021). *STEM etkinliklerinin okul öncesi öğretmen adaylarının bilgi işlemsel, eleştirel ve çok boyutlu 21. yüzyıl becerilerine etkisi.* Yayımlanmamış yüksek lisans tezi. Kastamonu Üniversitesi, Kastamonu.

Taşpınar, M. (2017). *Sosyal bilimlerde SPSS uygulama nicel veri analizi*. Pegem Akademi Yayıncılık.

Tekin, S. (2020). *Mühendislik temelli robotik uygulamaları içeren STEM öğretim yaklaşımının eleştirel düşünme ve mesleki tercihine etkisi.* Yayımlanmamış yüksek lisans tezi. Erzincan Binali Yıldırım Üniversitesi, Erzincan.

Topsakal, İ. (2018). *Probleme dayalı STEM öğretim yaklaşımının öğrencilerin öğrenme iklimlerine, eleştirel düşünme eğilimlerine ve problem çözme becerilerine yönelik algılarına etkisinin araştırılması.* Yayımlanmamış yüksek lisans tezi. Erzincan Binali Yıldırım Üniversitesi, Erzincan.

Topsakal, İ., Altun Yalçın, S. & Çakır, Z. (2022). The effect of problem-based STEM education on the students' critical thinking tendencies and their perceptions for problem-solving skills. *Science Education International, 33*(2), 136-145. https://doi.org/10.33828/sei.v33.i2.1

Turan, S. & Özer Özkan, Y. (2019). Ulaşılan sonuçların doğruluğunun ve inandırıcılığının kontrolü. S. Turan (Ed.), *Eğitimde araştırma yöntemleri* içinde (s. 162-178). Nobel Akademik Yayıncılık.

Uludağ, G. & Erkan, N.S. (2020). Erken çocukluk döneminde fen eğitimi ve önemi. G. Uludağ (Edt.). *Erken çocukluk döneminde fen eğitimi - "çocuğun keşif yolculuğu"* içinde (ss. 2-33). Nobel Yayıncılık.

Ünal, M. (2019). *4-6 yaş okul öncesi çocuklarına etkinlik temelli STEM öğretim yaklaşımının bilimsel süreç becerilerine etkisinin incelenmesi.* Yayımlanmamış yüksek lisans tezi. Abant İzzet Baysal Üniversitesi, Bolu.

Üret, A. (2019). *STEM öğretim yaklaşımının anaokuluna devam eden 5 yaş çocuklarının yaratıcılık düzeylerine etkisi*. Yayımlanmamış yüksek lisans tezi. Yıldız Teknik Üniversitesi, İstanbul.

Yaşar, M.D. (2018). Performans ölçülmesi. S. Baştürk (Ed.). *Eğitimde ölçme ve değerlendirme* içinde (s. 155-174). Nobel Yayıncılık.

Yeşilyurt, S. & Çapraz, C. (2018). Ölçek geliştirme çalışmalarında kullanılan kapsam geçerliği için bir yol haritası. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 20*(1), 251-264.

Yıldırım, A. & Şimşek, H. (2018). *Sosyal bilimlerde nitel araştırma yöntemleri.* Seçkin Yayıncılık.

Yıldız, S. & Zengin, R. (2023). Türkiye'de okul öncesi fen eğitimine yönelik yapılan araştırmaların analizi: meta-sentez çalışması. *Fırat Üniversitesi Sosyal Bilimler Dergisi, 33*(3), 1183-1197.

Yore, L. D., Hand, B., Goldman, S. R., & Mintzes, J. J. (2014). Scientific literacy for decision making and the social construction of scientific knowledge. *International Journal of Science Education, 36*(10), 1663-1678.