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ChatGPT in early childhood STEM education: Can it be an innovative tool to overcome challenges?

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Abstract

The aim of this study is to determine the effectiveness of using ChatGPT, an artificial intelligence-supported tool, to overcome the challenges in the implementation of early childhood STEM education based on teachers' views. In the study, a case study, which is a qualitative research method, was used. The participants of the study consisted of 43 early childhood teachers specialized in the field of STEM education who were determined by purposeful sampling method. Within the scope of the study, a training program was developed for teachers to integrate ChatGPT into early childhood STEM education and teachers voluntarily participated in this program. During the training process, the researchers collected data through observation reports and semi-structured interviews conducted after the training. The collected data were subjected to content analysis using MAXQDA software, and themes, categories and codes were identified. The findings revealed the teachers' views that the use of ChatGPT in early childhood STEM education would be beneficial. It was determined that ChatGPT would provide advantages such as guidance, effective use of existing materials, the opportunity to design student-specific activities, and the potential to complete teachers' missing knowledge. However, teachers also think that ChatGPT may cause negative situations such as technological addiction, regression in social skills, damage to the teacher-student relationship and misinformation. In conclusion, ChatGPT can benefit students' education.

Keywords Early childhood STEM education · ChatGPT · Artificial intelligence · Challenges in STEM education

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1 Introduction

Early childhood is a critical period for children's brain development and learning abilities (Catherwood, 2000; Maggi et al., 2005; Schiller, 2010). This period is the natural starting point for learning and becoming interested in STEM subjects (Moomaw, 2013; Moomaw & Davis, 2010; Uğraş & Genç, 2018). Many countries make arrangements for education programs by emphasizing the importance of STEM education in early childhood (Brenneman et al., 2019; Çiftçi & Topçu, 2022; Dejarnette, 2016; Jamil et al., 2018; Murphy et al., 2019; Simoncini & Lasen, 2018; Uğraş & Genç, 2018). However, many challenges are encountered in the process of STEM education in early childhood (Abdul Nasir Kiazai et al., 2020; Amran et al., 2021; Demircan, 2022; Malone et al., 2018; Wan et al., 2021). These challenges include planning effective STEM activities (EL-Deghaidy et al., 2017; Shernoff et al., 2017; Tao, 2019), teachers' lack of knowledge (Campbell et al., 2018; Çiftçi & Topçu, 2022; Uğraş & Genç, 2018; Yıldırım, 2021), lack of materials (Amran et al., 2021), individual differences among students (Çiftçi & Topçu, 2022; Demircan, 2022), classroom management (Demircan, 2022; EL-Deghaidy et al., 2017; Lange et al., 2022), time management (Abdul Nasir Kiazai et al., 2020; Ejiwale, 2013; Shernoff et al., 2017), and a lack of student-teacher motivation (EL-Deghaidy et al., 2017; Tao, 2019). These shortcomings are barriers to teachers' willingness to implement STEM education (Wan et al., 2021). These challenges make it difficult for teachers to implement STEM education effectively. In this context, the challenges encountered in the implementation of early childhood STEM education stand out as a situation that needs to be overcome and effectively addressed (Wan et al., 2021).

Artificial intelligence has experienced rapid growth in recent years in various research areas such as robotics, education, and autonomous driving, leading to social transformations (Ahmad et al., 2021; Chen et al., 2020; Kasneci et al., 2023; Kusters et al., 2020; Montenegro-Rueda et al., 2023; Owoc et al., 2021; Reiners et al., 2021). Among these developments, the field of education also occupies an important place. Especially in STEM education, these developments offer important opportunities for the integration of technology (Okonkwo & Ade-Ibijola, 2021). These opportunities can provide support to overcome the challenges faced in the STEM education process. Advances in artificial intelligence play an important role in overcoming challenges in early childhood STEM education (Okonkwo & Ade-Ibijola, 2021). This role can be realized through the capabilities of artificial intelligence. In general, AI is defined by the ability of a computer system to mimic the behavior of the human brain (Guo, 2023; Marino et al., 2023; Montenegro-Rueda et al., 2023). This ability includes utilizing external data, learning through training, and achieving specific goals (Guo, 2023; Kasneci et al., 2023; Marino et al., 2023; Montenegro-Rueda et al., 2023).

Education is a complex process that goes beyond mere knowledge acquisition, and in this context, AI applications are making a significant impact by increasing the efficiency of educational processes, promoting global learning, personalizing learning, creating richer content, and optimizing educational management (Ahmad et al., 2021; Chen et al., 2020; Owoc et al., 2021). However, educators are not utilizing the full potential of AI in the context of teaching and learning (Celik, 2023). The

main reason for this is that educators are concerned about some important challenges and ethical issues (Farrokhnia et al., 2023; Kasneci et al., 2023; Owoc et al., 2021). Therefore, issues such as data privacy, equal access to education and the role of educators should be carefully considered (Chen et al., 2020; Dwivedi et al., 2021; Su & Yang, 2022). It is also critical that these issues are taken seriously so that AI can be offered to all students in a fair and beneficial way (Atlas, 2023; Farrokhnia et al., 2023). More research is needed on how humans can coexist with AI and how to minimize the negative effects of technology (Duan et al., 2019). In this context, it is of great importance to strike a balance between technology and educators, focusing on the holistic development of students and their preparedness for an ever-changing world (Chan & Zary, 2019; Kusters et al., 2020; Rahimi & Mosalli, 2024; Reiners et al., 2021; Timotheou et al., 2023). In this context, the main aim of the study is to determine the effectiveness of using ChatGPT to overcome the difficulties experienced in the implementation of early childhood STEM education based on teacher opinions.

2 Literature review

2.1 STEM education in early childhood

Early childhood covers a critical period of life from birth to age 8 and is characterized by rapid brain development and learning ability (Catherwood, 2000; Maggi et al., 2005; Schiller, 2010). Especially with the increase in global economic competition, many countries are placing more emphasis on STEM (Science, Technology, Engineering, and Mathematics) fields in early childhood and establishing educational policies in order for the future workforce to be competitive (Brenneman et al., 2019; Çiftçi & Topçu, 2022; Jamil et al., 2018; Uğraş & Genç, 2018). For the effectiveness of STEM education policies, importance should be given from an early age (Çiftçi et al., 2022). In Turkey, the STEM Education Report published by the Ministry of National Education in 2016 emphasizes that, in addition to focusing on STEM education in primary, middle, and high schools, this field should not be neglected in early childhood (Ministry of National Education (MoNE), 2016). However, it is observed that research, projects, and studies on STEM education in early childhood are insufficient in Turkey (Çiftçi et al., 2022; Dönmez & Gülen, 2024). While the number of scientific studies on STEM in primary, secondary, high school, and university levels is high, the number of studies in early childhood is limited (Uğraş & Genç, 2018). Especially in the United States, studies on STEM education in middle and high school are common, while little attention is paid to this field in primary and early childhood education (Çiftçi et al., 2022; Su et al., 2023; Wang et al., 2017). In 2013, President Barack Obama stressed the significance of introducing STEM education at a young age and highlighted the need for children to engage in both consuming and producing science. Efforts are currently underway to involve children in STEM at a young age in response to the demand for skilled scientists and engineers in the United States (Holdren et al., 2013). Norway implemented a strategy plan named 'STEM of Course' in 2002 with the goal of enhancing STEM teaching abilities through-

out all educational levels, from early childhood to secondary education (Ministry of National Education (MoNE, 2016). However, Turkey and many other countries do not give enough importance to STEM education in early childhood. It is observed that early childhood education and STEM are not sufficiently included in the education programs of countries such as Australia, Finland, Germany, Ireland, and the United Kingdom (Moore et al., 2020; Timms et al., 2018). Therefore, more studies, projects, and research are needed for the successful implementation of STEM education in early childhood.

Early childhood is a natural starting point for the ability to learn STEM subjects and children naturally express their interest and curiosity in this field (Moomaw, 2013; Moomaw & Davis, 2010; Uğraş & Genç, 2018). In this period, STEM education offers a learning environment where scientific knowledge and processes, critical thinking skills, and curiosity can be developed (Debora & Pramono, 2021; John et al., 2018). Research shows that early childhood STEM education provides a range of positive outcomes such as encouraging children to develop the ability to explore, enabling them to think independently (Jamil et al., 2018; Uğraş, 2019), increasing the number of students working in STEM fields (MacDonald et al., 2020; Van Keulen, 2018; Buchter et al., 2017), preparing children for school and helping them understand basic concepts (Van Keulen, 2018), increasing their beliefs in STEM subjects (MacDonald et al., 2020), enriching their vocabulary, and improving their literacy skills (Buchter et al., 2017; MacDonald et al., 2021). These results emphasize the importance of STEM education in early childhood. As a result, early life experiences can be determinant of later experiences, and therefore focusing on early childhood education is seen as a critical step to better respond to future workforce demands (Halfon & Hochstein, 2002; Lusiyah Simanjuntak, 2022).

3 What is ChatGPT?

ChatGPT is an artificial intelligence application based on the GPT (Generative Pre-trained Transformer) architecture, a pre-trained language model. This model, developed by OpenAI, was developed to successfully perform language-based artificial intelligence tasks such as text generation, question answering and dialog systems (OpenAI, 2024). According to OpenAI, the ChatGPT model has been trained on large amounts of internet text data and is capable of generating human-like text. The model uses a transformer architecture that enables parallel data processing, making it highly suitable for natural language processing tasks. ChatGPT has been fine-tuned on speech data, especially for use in tasks such as answering questions or generating text in dialog systems. This fine-tuning process allows the model to learn the unique nuances and patterns of spoken language, increasing its ability to produce human-like responses. In addition to its text generation capability, ChatGPT is also capable of text understanding and interpretation. This model is suitable for a wide range of natural language processing tasks. The model can be used in different applications such as customer service chatbots, virtual assistants or voice-controlled devices (OpenAI, 2024).

ChatGPT has been successfully used for important tasks such as answering questions, providing resources, evaluating assignments, and lesson planning (Dowling & Lucey, 2023; Mhlanga, 2023; Tate et al., 2023; Warr et al., 2023). This application has great potential in human education by providing customized and responsive AI supports to students and teachers (Atlas, 2023; Baidoo-Anu & Owusu Ansah, 2023; Opara et al., 2023). Researchers state that ChatGPT has intelligent speech capabilities in the educational context and can have a great positive impact in the field of education (Ali et al., 2023; Lo, 2023; Tlili et al., 2023). On the other hand, there are also critics of the use of ChatGPT in education. These critics emphasize that negative effects such as the spread of misinformation and prejudices, violation of academic integrity, job loss and increased inequalities can be seen at all levels of learning and teaching (Kasneci et al., 2023).

The emergence of ChatGPT has brought great public interest and global concern about the potential of AI technologies in education (Chen & Lin, 2023; Dwivedi et al., 2021; Su & Yang, 2022). This so-called "ChatGPT Tsunami" has created uncertainty among teachers and students while offering hope for better education (Luo et al., 2023). The literature review shows that conceptual studies generally dominate, empirical research is limited, and there is a lack of comprehensive knowledge about the role and functions of AI technologies in education. Some empirical studies have examined how ChatGPT can be used in different courses and grade levels. For example, existing ChatGPT research, such as Cooper's (2023) work on science education and Atlas's (2023) work on higher education, have examined how AI can be used in terms of student learning and educator teaching (Atlas, 2023; Cooper, 2023).

4 STEM education and ChatGPT

Developments in artificial intelligence and Natural Language Processing (NLP) offer significant opportunities for the integration of technology, especially in STEM education (Okonkwo & Ade-Ibijola, 2021). Khosravi et al. (2023) emphasize the educational advantages of chatbots such as continuous accessibility and scalability (Khosravi et al., 2023). They argue that chatbots can revolutionize education in ways such as engagement, personalization, educator support, and student understanding, especially in cases that require special support in STEM (Javaid et al., 2023; Kuhail et al., 2023). In this context, ChatGPT has recently attracted much attention as an educational tool in STEM learning (Baidoo-Anu & Owusu Ansah, 2023). This tool can communicate persuasively with users in a natural language and support traditional pedagogical practices (Atlas, 2023). Perhaps the most important feature of ChatGPT is that users can communicate in their native language without the need for any programming language knowledge (George & George, 2023). Users can "talk" to ChatGPT in a natural way and ChatGPT can respond in their language or in another language of their choice. This feature is recognized as one of the key factors that enabled ChatGPT to attract 100 million users within just two months of its launch (Wu et al., 2023), and a large proportion of these users are students. OpenAI ChatGPT1 uses GPT-based NLP techniques to generate human-like responses using a large repository of internet text data (Wang et al., 2023). This provides support to

teachers and students by giving them ideas, especially in STEM education (Verma, 2023).

ChatGPT offers great advantages to students and teachers by providing access to instant and vast information on STEM subjects. Thanks to its ability to provide customized support to students, it can offer learning experiences that match their learning needs and pace (Verma, 2023). Teachers can teach students more effectively by using ChatGPT for lesson planning, material development, and student support (Koraishi, 2023; Van Den Berg & du Plessis, 2023). Moreover, ChatGPT can also help students gain the ability to solve and analyze complex STEM problems (Liang et al., 2023; Rahimi, 2024; Vasconcelos & Santos, 2023). It can provide an opportunity to create pathways for understanding and using concepts in the STEM field (Vasconcelos & Santos, 2023). In addition, ChatGPT is available in various digital environments, so students can access it easily. This opportunity can contribute to the dissemination of education by providing students with access to opportunities to learn STEM-related topics regardless of time and place (Rahman & Watanobe, 2023). For these reasons, ChatGPT is seen as an important tool in STEM education (Vasconcelos & Santos, 2023).

The aims of early childhood STEM education include supporting language development, arousing interest in STEM subjects, increasing motivation to learn, improving problem-solving skills, and encouraging individualized learning bulunmaktadır (Uğraş & Genç, 2018; Wan et al., 2021). ChatGPT has technical features that can support these goals. For example, it can support language development by interacting with students, and it can increase children's interest and motivation in STEM fields by offering interactive learning experiences and activity suggestions suitable for the individual characteristics of the student. It can strengthen students' problem-solving skills by asking questions and providing guidance. Therefore, it is thought that ChatGPT can effectively support the goals of early childhood STEM education.

In the literature, the challenges encountered in the early childhood STEM education process have been reported in many studies (Bal & Bedir, 2021; Kiazai et al., 2020; Ramli et al., 2017; Shernoff et al., 2017). Wan et al. (2021) conducted a literature review on the problems encountered in STEM education in early childhood (Wan et al., 2021). Çiftçi and Topçu (2022) conducted a study with pre-service teachers to overcome the difficulties (Çiftçi & Topçu, 2022). Shernoff et al. (2017) studied the difficulties and requirements of teachers across all disciplines when incorporating STEM education into educational settings (Shernoff et al., 2017). Ramli et al. (2017) addressed the challenges in STEM teaching practices (Ramli et al., 2017). These studies can play an important role in providing information about the challenges that arise in the STEM education process in early childhood. In this context, it is important to consider how research can contribute to overcoming the challenges in the early childhood STEM education process. In this context, the main purpose of this study is to determine the effectiveness of using ChatGPT to overcome the challenges in the implementation of early childhood STEM education based on teachers' views.

5 Method

In this study, a case study using a qualitative research method was used. A case study is a research method used to more closely investigate and describe one or more limited situations, events, phenomena, or communities (Creswell, 2013; Merriam & Tisdell, 2015). Case studies examine a contemporary occurrence within an actual situation (Yin, 2018). It specifically examines individuals, programs, processes, and events in the real world (Glesne, 2016; Yin, 2018). This strategy assists in shaping social, cultural, and physical linkages by concentrating on specific processes associated with phenomena (Maxwell, 2012). In this context, the use of AI-supported tools in educational fields and researching their effects is a current phenomenon. In this context, the effectiveness of using ChatGPT to overcome the difficulties encountered in the implementation of early childhood STEM education was examined on the basis of teacher views.

5.1 Participant

The participants of the study consisted of 43 primary school teachers working in grades 1–3 in public schools in Turkey in the 2023–2024 academic year. The maximum variation sampling technique, one of the purposive sampling methods, was used to identify these teachers. Purposive sampling method was used to determine these teachers. Purposive sampling involves selecting rich situations in order to reach the necessary data in more depth to address the research purpose. This sampling method is appropriate when it is aimed at studying individuals or a group with certain characteristics (Büyüköztürk et al., 2012). The maximum diversity sampling technique enabled us to select a large sample that included important differences among the participants (Patton, 2014). Within the scope of maximum diversity sampling, attention was paid to the STEM education experiences of the participating teachers, the grade levels, and the class sizes. The goal was to maximize the diversity of potential data collection within the constraints of the available resources. This method provides the opportunity to examine the potential of ChatGPT as an innovative tool in early childhood STEM education and its impact against the challenges that may be encountered from a broad perspective. Teachers voluntarily participated in the study, and a consent form was obtained from each of them. Instead of the participants' real names, names that characterize them (such as T1, T2, T3, etc.) were used. Of the participant teachers, 32 were female and 11 were male, and their ages ranged between 23 and 38. Thirteen of the participants were 1st grade teachers, 17 were 2nd grade teachers, and 17 were 3rd grade teachers. All of the teachers participating in the study had previously received STEM education and used it in their lessons. Among these teachers, 9 of them have 1–3 years, 7 of them have 3–5 years, and 26 of them have 5 years or more of STEM education implementation experience. Seventeen of the participants teach in the center, and 26 of them teach in rural areas. There are 13 teachers with a class size of 1–20 students, 11 teachers with 21–40 students, and 19 teachers in classes with 40 or more students. Six teachers who participated in the study had positive views about artificial intelligence, while 37 teachers had negative views. These

teachers will receive training on how to integrate ChatGPT into STEM education. The self-qualifications of the participants are presented in Table 1.

The research problem of this study is; "What are the opinions of teachers about the effectiveness of using ChatGPT to overcome the difficulties in the implementation of STEM education in early childhood?"

5.2 Implementation process

In this study, a training program was prepared to integrate ChatGPT into STEM education. While preparing this training program, the literature was reviewed and a draft program was prepared. This draft program was finalized by taking the opinions of an expert in the field of early childhood STEM education and an expert in the field of artificial intelligence in education. The headings in the content of the prepared training program are given below:

- Basic STEM Concepts and STEM Education in Early Childhood.
- The Effects of STEM Education in Early Childhood on Children's Development.
- Challenges in Early Childhood STEM Education in the Literature.
- Artificial Intelligence and ChatGPT: Basic Concepts and Mechanisms.
- Integration of ChatGPT into STEM Education in Early Childhood.
- Briefing for Teachers on Introducing and Using ChatGPT.
- Applications for the Integration of ChatGPT into STEM Education.
- Discussion and Review.
- Evaluation.

In the first lessons, basic STEM concepts, STEM education in early childhood, difficulties encountered in the STEM education process in the literature and their solutions were given. In the following lessons, training was given on artificial intelligence and basic concepts, what ChatGPT is and its basic functioning, how ChatGPT can be integrated into STEM education, and how the problems encountered can be solved with ChatGPT. Sample activities were carried out to solve these problems and teachers were allowed to discuss among themselves.

5.3 Data collection

The data for the study were collected through semi-structured interview forms and researcher observation reports; thus, data triangulation was performed. Two or more data sets are used for triangulation (e.g., Heale & Forbes, 2013). Within the scope of triangulation, data were collected at separate times (Denzin, 2017). The semi-structured interview form and researcher observation reports were used to examine teachers' views on the effectiveness of using ChatGPT to solve the problems encountered in the implementation of STEM activities in early childhood. In addition to the questions in the semi-structured interview forms, the teachers were asked follow-up questions such as *"can you give me more information about…"* and *"can you explain… situation to me with an example?"*

Table 1 Participants' self-qualifications

Participant	Gender Female (F) Male (M)	Age 23–38	Education status	The region of duty	Class assigned	Class size of the assigned	STEM education experience	Opinions on artificial intelligence.
P1	Male	30	Undergraduate	Rural Region	3rd grade	21–40 students	5 Years and above	Negative
P2	Female	36	Undergraduate	City Center	1st grade	40 or more students	5 Years and above	Negative
P3	Male	32	Master's Degree	City Center	3rd grade	21–40 students	5 Years and above	Negative
P4	Female	35	Undergraduate	City Center	3rd grade	40 or more students	5 Years and above	Negative
P5	Female	32	Undergraduate	City Center	2nd grade	21–40 students	5 Years and above	Negative
P6	Female	26	Undergraduate	Rural Region	1st grade	1–20 students	3–5 Years	Negative
P7	Female	26	Undergraduate	Rural Region	1st grade	1–20 students	3–5 Years	Negative
P8	Male	26	Undergraduate	Rural Region	2nd grade	1–20 students	1–3 Years	Negative
P9	Female	28	Undergraduate	Rural Region	1st grade	1–20 students	1–3 Years	Negative
P10	Female	35	Undergraduate	Rural Region	3rd grade	21–40 students	3–5 Years	Negative
P11	Male	31	Undergraduate	City Center	3rd grade	40 or more students	5 Years and above	Negative
P12	Female	29	Master's Degree	Rural Region	2nd grade	1–20 students	1–3 Years	Positive
P13	Female	32	Master's Degree	City Center	1st grade	40 or more students	5 Years and above	Positive
P14	Female	35	Undergraduate	Rural Region	2nd grade	21–40 students	5 Years and above	Negative
P15	Male	38	Undergraduate	City Center	2nd grade	40 or more students	5 Years and above	Negative
P16	Female	35	Undergraduate	City Center	2nd grade	40 or more students	5 Years and above	Negative
P17	Female	34	Undergraduate	City Center	1st grade	40 or more students	5 Years and above	Negative
P18	Male	34	Undergraduate	Rural Region	3rd grade	21–40 students	1–3 Years	Negative
P19	Female	34	Undergraduate	City Center	1st grade	21–40 students	5 Years and above	Negative
P20	Female	24	Undergraduate	Rural Region	2nd grade	1–20 students	1–3 Years	Negative
P21	Female	26	Undergraduate	Rural Region	1st grade	1–20 students	1–3 Years	Negative
P22	Male	32	Undergraduate	Rural Region	3rd grade	40 or more students	5 Years and above	Negative
P23	Female	32	Undergraduate	Rural Region	3rd grade	40 or more students	1–3 Years	Negative
P24	Female	35	Undergraduate	Rural Region	2nd grade	1–20 students	5 Years and above	Negative
P25	Male	37	Undergraduate	Rural Region	2nd grade	1–20 students	5 Years and above	Negative
P26	Female	31	Undergraduate	City Center	3rd grade	40 or more students	5 Years and above	Negative

Table 1 (continued)

Participant	Gender Female (F) Male (M)	Age 23–38	Education status	The region of duty	Class assigned	Class size of the assigned	STEM education experience	Opinions on artificial intelligence.
P27	Female	31	Undergraduate	City Center	3rd grade	21–40 students	5 Years and above	Negative
P28	Female	37	Undergraduate	Rural Region	1st grade	40 or more students	5 Years and above	Negative
P29	Female	37	Undergraduate	Rural Region	2nd grade	40 or more students	5 Years and above	Negative
P30	Female	36	Undergraduate	Rural Region	2nd grade	40 or more students	5 Years and above	Negative
P31	Male	34	Master's Degree	Rural Region	2nd grade	1–20 students	3–5 Years	Negative
P32	Female	36	Master's Degree	City Center	3rd grade	40 or more students	3–5 Years	Negative
P33	Female	28	Master's Degree	Rural Region	3rd grade	40 or more students	3–5 Years	Positive
P34	Female	29	Master's Degree	Rural Region	3rd grade	21–40 students	3–5 Years	Negative
P35	Male	32	Master's Degree	City Center	2nd grade	40 or more students	5 Years and above	Negative
P36	Female	35	Undergraduate	Rural Region	1st grade	21–40 students	5 Years and above	Negative
P37	Female	36	Master's Degree	City Center	2nd grade	40 or more students	5 Years and above	Negative
P38	Female	35	Master's Degree	City Center	2nd grade	40 or more students	5 Years and above	Negative
P39	Female	29	Master's Degree	Rural Region	3rd grade	21–40 students	3–5 Years	Positive
P40	Female	24	Undergraduate	Rural Region	3rd grade	1–20 students	1–3 Years	Negative
P41	Female	35	Master's Degree	City Center	1st grade	40 or more students	5 Years and above	Negative
P42	Female	24	Undergraduate	Rural Region	2nd grade	1–20 students	1–3 Years	Positive
P43	Male	23	Undergraduate	Rural Region	1st grade	1–20 students	1–3 Years	Positive

5.4 Data collection tool

A semi-structured interview form was prepared by the researchers in order to determine teachers' views on the effectiveness of using ChatGPT to overcome the challenges they face in early childhood STEM education. This form was created by identifying the challenges encountered in the early childhood STEM education process in the literature. This form was examined by three experts in the fields of early childhood education, STEM education in early childhood, and artificial intelligence applications in education. The interview form was finalized according to the feedback received from the experts. The semi-structured interview form is presented in Appendix 1. The use of a semi-structured interview form was preferred as it allowed for an in-depth and comprehensive determination of the effectiveness of ChatGPT in overcoming the challenges encountered in early childhood STEM education. In addition to the semi-structured interview form as a data collection tool, forms were also used to observe the activities of the teachers during the training process. In addition to the semi-structured interview form as a data collection tool, forms were also used to observe teachers' activities during the training process.

5.5 Data analysis

In this study, thematic content analysis was used to describe early childhood teachers' responses to questions about the integration of ChatGPT into STEM education. Thematic content analysis is a type of content analysis used to identify, analyze, organize, describe, and report themes (Braun & Clarke, 2006; Silverman, 2014). An inductive approach was adopted for data analysis (Bengtsson, 2016). This approach is defined as a systematic classification process for subjective interpretation of textual data content, including coding and theme or category identification (Elo & Kyngäs, 2008; Hsieh & Shannon, 2005). The researchers determined the themes in the study through their discussions, without building on the themes previously identified in the literature. Therefore, the researchers used an inductive content analysis approach. Face-to-face interviews with teachers lasted approximately 40–45 min. At the end of the interview, the teachers were asked to listen to their recorded answers again and confirm them. The Findings section includes quotations from the teachers' responses. After the data obtained was processed in the MAXQDA program, a comprehensive coding framework with frequency and percentage values was created. Two researchers independently coded the analyses of 40% of the data from the interviews. Since 85% of the researchers' independent codings agreed, only one researcher examined the remaining data. As a result of the controls, the codes that were in disagreement were discussed, and the codes and themes that were agreed upon were used in the research. In addition to the practices to increase the reliability of the findings, the consistency of the findings was increased by comparing the interview and researcher diary data. The findings obtained from the interviews were read to some of the participants, and feedback was received about the accuracy and comprehensibility of the comments made. This feedback was used to assess whether the comments reflected the participants' actual views. In the interviews with the participants, it was observed that no new codes emerged and the existing codes stabilized. This led to the repeated

emergence of similar themes and patterns. This finding indicates that the rate of obtaining new information decreased and that certain themes were adequately represented. Therefore, it was concluded that data saturation was reached.

5.6 Findings

The results of the content analysis of the data obtained from the interviews conducted at the end of the training program attended by the teachers participating in the study to integrate ChatGPT in STEM education are presented below in tables.

5.6.1 Teachers' views on how ChatGPT can contribute to overcoming the challenge of lack of materials in early childhood STEM education

The theme, categories, and codes created for the contributions that ChatGPT can provide to overcome the difficulty of a lack of materials in early childhood STEM education are presented in Table 2.

The teachers participating in the study stated that ChatGPT provides ideas and guidance for effective use of materials in order to overcome the difficulty of a lack of materials in STEM education. Teachers emphasized that ChatGPT can guide material design and individualized education in STEM education. In addition, it was also stated that it would be beneficial in terms of efficient use of materials and gaining new perspectives on the use of materials. For example, T18, who works in a rural area and has limited experience in STEM education, said "*... I am happy that I will be able to offer more effective STEM education to my students who are in economically difficult situations. ChatGPT's guidance will relieve me a lot…"* about using ChatGPT more efficiently with its limited number of materials. Likewise, teachers working in rural areas, such as T_{23} and T_{35}, stated that ChatGPT can help with guidance and planning activities suitable for students. T_{17}, who works in the city center and has more STEM education experience than other teachers, said *"…ChatGPT is like the invention of the century for my classes…"* with a laugh. The respondent was then asked why he/she made such an evaluation and he/she answered *"… I think I can overcome the difficulties I have in providing effective STEM education to students with different characteristics due to the high class size with the guidance he will provide…"* T_{11}, who works in a good school district and teaches in a school with crowded class sizes, stated *"…due to the high number of students*, *I could not get enough materials*, *and I did not know how to use the materials in the classroom for different activities.*

Table 2 Teachers' views on how Chatgpt will contribute to the lack of materials in STEM education

Themes	Category	Code	*f*
Overcoming the challenge of lack of materials with ChatGPT	Assistance in Material Design	STEM activity suggestion	35
	Individualized education	Material creation	28
		Story design	25
	Productivity	Efficient use of materials	20
		Flexible teaching tools	15
	Gaining Perspective	Innovative perspective	15

Thanks to ChatGPT, I am happy that I will be able to plan activities according to the materials I have in a short time…". Teacher T_{43}, who works in the village and is the youngest of the study group in terms of age and has 2 years of experience in STEM education, stated *"… I didn't know much about the region I was assigned to. I also had problems in storytelling the events that students might encounter in their lives. I think that ChatGPT's guidance in creating stories according to the characteristics of the students will relieve me a lot…"* Teachers in similar situations, such as T_{43}, mentioned its advantages in creating stories suitable for students. The participant views expressed in this way reflect the various advantages ChatGPT offers to teachers and its practical contributions to STEM education.

5.6.2 Teachers' opinions on how ChatGPT can contribute to the processes of overcoming teachers' own deficiencies in early childhood STEM education

The theme, categories and codes created for the contributions that ChatGPT can provide in the processes of overcoming the teacher's own deficiencies in early childhood STEM education are presented in Table 3.

It was stated that teachers saw ChatGPT as a supportive tool for providing guidance and information about the individual deficiencies they encountered during STEM education. In addition, the ability to develop creative content on the topics requested by teachers and to make suggestions suitable for individual characteristics was particularly emphasized. Based on the differences in experience in the teaching profession, the problems experienced by novice teachers in STEM education practices were tried to be solved with the guidance service provided by ChatGPT, especially in creating appropriate stories for students and planning activities. For example, T_{39} stated his opinion as *"…I received training on STEM education during my undergraduate studies. However, I had difficulties implementing STEM education in my classroom. For example, creating stories suitable for students and planning activities were very difficult for me during the process. I think I will overcome these difficulties with the guidance of ChatGPT…"* Like T_{39}, $T_{31–34}$, working in similar regions, also expressed similar ideas. In addition, the difficulties of senior teachers in following current developments and their need to learn about current approaches in STEM education through ChatGPT were expressed. For example, T_{15}, the most senior member of the study group, stated, *"… I cannot follow some current developments, especially what are the current approaches when implementing STEM education? And I can learn how to use them through ChatGPT…".* T_{13} and T_{16}, who have

Table 3 Teachers' views on how Chatgpt will contribute to the process of overcoming their deficiencies in STEM education

Themes	Category	Code	*f*
Overcoming problems due to individual shortcomings with ChatGPT	Information Provision	Resource provision	38
		Keeping up to date with the latest information.	30
	Being a Guide	Creative content development.	29
		Bireysel özelliklere göre önerilerde bulunması Making recommendations based on individual characteristics.	27

similar seniority like T_{15}, also stated *"...I think that I will be able to overcome my missing knowledge about STEM fields with ChatGPT, especially the information I will gain about how to use the information, which will increase the efficiency of my education process..."*. In this context, it was stated that teachers saw ChatGPT as an effective assistant in terms of providing access to up-to-date information and resources that they lacked. As a result, teachers evaluated ChatGPT as a tool through which they could fill their gaps in knowledge in the field of STEM education and make their educational processes more efficient. This tool has the potential to enrich and strengthen teachers' educational practice.

5.6.3 Teachers' opinions on how ChatGPT can contribute to overcoming problems related to Individual differences of students in early childhood STEM education

The theme, categories and codes created for the contributions that ChatGPT can provide in the process of overcoming the problems related to the individual differences of your students in early childhood STEM education are presented in Table 4.

It was stated that ChatGPT can provide guidance with its personalization feature in overcoming the difficulties faced by teachers due to students' individual differences within the scope of STEM education. In addition, teachers stated that ChatGPT can provide important support for individualization strategies in the process. In particular, it was emphasized that they planned to use ChatGPT to prepare individual learning plans for students and to develop content suitable for student needs. For example, one of the teachers, T_2, stated *"...my class size is high, so I plan to make use of ChatGPT while making appropriate plans for the students..."* and was asked how you plan to use ChatGPT to provide support while realizing this, and T_2 stated *"...Students are at different levels and have different interests. I think it can guide me to group students with similar characteristics and plan according to their levels and interests..."*. T_9, who works in rural areas, stated *"...although my class size is small, the interests of the children are very different. For this reason, I think I can overcome the difficulties I have in planning the training with the ideas I will get from ChatGPT..."*. T_8 and T_{12} also expressed similar things to T_9. In this context, it is seen that teachers evaluate the challenges they face in STEM education as an effective tool to adopt the individualized teaching strategies of ChatGPT and to create content appropriate to student needs.

Table 4 Teachers' views on how Chatgpt will contribute to overcome problems related to students' individual differences in STEM education

Theme	Category	Code	f
Overcoming the Challenge of Students' Individual Differences with ChatGPT	Individualization Strategy	Preparing individual learning plans.	28
		Preparing content suitable for student needs.	23

Table 5 Teachers' views on how ChatGPT will contribute to overcome classroom management problems they face in STEM activities

Theme	Category	Code	*f*
Overcoming Classroom Management Challenges with ChatGPT	Personalized Content	Developing student-appropriate content	25
	Classroom Interaction	Increasing student engagement	23
	Guidance	Guidance in solving classroom management problems	20

5.6.4 Teachers' views on how ChatGPT can contribute to overcoming classroom management challenges in early childhood STEM education

The theme, categories and codes created for the contributions that ChatGPT can provide in the process of overcoming classroom management challenges in early childhood STEM education are presented in Table 5.

Teachers emphasized the potential of ChatGPT to provide individualized content with student interaction and guidance to overcome the classroom management challenges they face in STEM education. It was stated that ChatGPT will provide important support to teachers, especially in preparing individual learning plans with in-class interaction and guidance. It is revealed that teachers see ChatGPT as an effective solution to the classroom management difficulties that arise due to the lack of planning activities for students' interests. For example, T_5 stated *"… STEM education does not attract the interest of some children in the class, and this causes me to have classroom management problems. I think these children can be more motivated and actively participate in education by interacting with ChatGPT…"*. Also, T_{19} and T_{27} stated *"…I think I can easily overcome classroom management problems because it will help me plan activities for students' interests…"*. T_3, whose confused facial expressions about the effectiveness of ChatGPT during the implementation process of the training stated his opinions as *"…Planning activities for students' interests was exhausting for me. Also, being able to interact with ChatGPT will enable children to be involved in more in-depth activities…"*. In this context, it is seen that teachers recognize the effective role of ChatGPT in classroom management in the STEM education process and will evaluate the potential of this tool in providing classroom interactions and individualized content for students.

5.6.5 Teachers' views on how ChatGPT can contribute to overcoming student motivation challenges in early childhood STEM education

The theme, categories and codes created for the contributions that ChatGPT can provide in the process of overcoming the challenge of student motivation in early childhood STEM education are presented in Table 6.

STEM education teachers emphasized the individualized content and guidance opportunities offered by ChatGPT to overcome the difficulties in student motivation. In particular, it was stated that ChatGPT can make an important contribution to overcoming the student motivation challenges encountered in the STEM education process, as STEM education can be planned according to the characteristics and competencies of students, appropriate feedback can be given to students in a short time, and students can get ideas for their special interests. During the training process for teachers, T_{31} paid special attention to this issue in practical applications. In the inter-

Table 6 Teachers' views on how Chatgpt will contribute to overcome student motivation problems in STEM education

Theme	Category	Code	*f*
Overcoming student motivation challenges with ChatGPT	Personalized Content	Creating content according to the learner	28
		Individualized learning experiences	27
		Real-Time Feedback	20
	Guidance	Providing guidance on increasing student motivation	15

view with T_{31}, he stated *"...The problem of student motivation is one of the biggest problems I have experienced in my STEM education process. Therefore, I was very excited..."*. Then, the question of why you were having this problem and how you think you can solve it with ChatGPT was asked. T_{31} stated his thoughts as *"...I could not include all students in the STEM education process due to the large class size. Some of them were very reluctant to participate in the process. With ChatGPT, I think I can make plans that can attract students' interest..."*. Similarly, T_{32} and T_{37} shared similar difficulties and stated that ChatGPT can be used to increase student motivation. T_4, a teacher with a high Professional experience, stated his opinion as *"... It has been a long time since I graduated from high school. As a result, I sometimes felt that I was insufficient in terms of how to increase student motivation. I think I can overcome this deficiency with ChatGPT..."*. T_{35}, who has a master's degree, stated his opinion as *"... in general terms, I took courses and did applications for STEM education both during my undergraduate and graduate studies. However, I could not gain any experience with student motivation in these courses. This was a challenge I also faced. I hope we can overcome this challenge with ChatGPT..."*. These views show that ChatGPT has the potential to contribute positively to student motivation in STEM education.

5.6.6 Teachers' views on the effect of integrating ChatGPT in early childhood STEM education on students

The theme, categories and codes created for the opinions about the effect of integrating ChatGPT in early childhood STEM education on students are presented in Table 7.

There are various opinions and evaluations among teachers about the effect of STEM education with ChatGPT integrated on students. The training prepared for

Table 7 Teachers' views on the effect of ChatGPT's STEM activities on students

Theme	Category	Code	*f*
The Impact of ChatGPT on Students	Positive effect	Increasing student engagement	35
		Supporting Student Creativity	35
		Promoting individualized learning	35
		Strengthening problem solving skills	32
		Creating interactive learning experiences	30
	Negative effect	Technology addiction	35
		Decline in social skills	33
		Decreased teacher-student relationship	30
		Possibility of obtaining erroneous information	19

teachers was one of the most intensely discussed topics among teachers during the implementation process. In these discussions, although teachers emphasized the positive effects of ChatGPT, they also expressed serious concerns. A group of teachers thought that ChatGPT would make positive contributions to STEM education and stated that it would increase students' participation, problem-solving skills, and creativity. However, despite these positive views, a group of teachers emphasized the negative effects. For example, T_{41} stated *"…will increase students' participation in the STEM education process*, *problem solving*, *and creativity…"*, but T_{26}, who expressed that he had negative thoughts about artificial intelligence, expressed his anxiety by asking questions like *"…Where are the students' voice recordings or correspondence records collected?"* However, T_{27} stated *"…If doing research is only done with ChatGPT*, *we will disconnect children from books. Therefore*, *we need to create this awareness in children first…"* T_{38} stated his concern as *"…ChatGPT provides information based on existing texts according to our commands; if some of those texts have errors*, *incorrect learning may occur…"*. T_{11} stated his anxiety in different subjects as *""Before I started using ChatGPT in STEM education*, *my students used to constantly come to me and exchange ideas. However*, *after we started using-ChatGPT*, *we no longer came to me and interacted with each other. I also observed that the students do not exchange information among themselves. It worries me that this is addictive."* Due to the fact that most of the teachers had common concerns, there were opinions on the direction of negative effects as well as positive effects. In both the training and the process, the fact that they had life concerns made them feel that it would not be an obstacle for them to integrate ChatGPT into STEM education.

The categories and codes created in MAXQDA for the content analysis of the opinions of the teachers participating in the study on the use of ChatGPT in overcoming the challenges encountered in early childhood STEM education are shown in Fig. 1.

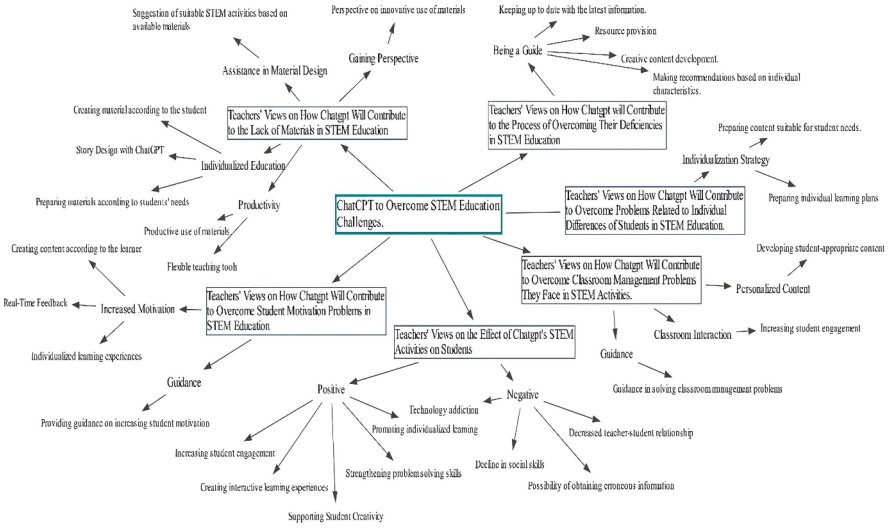

Fig. 1 ChatGPT to overcome STEM education challenges

When Fig. 1 is analyzed, it reflects the teachers' differing opinions on the potential effects of ChatGPT in early childhood STEM education. Many teachers seem to think that ChatGPT will be useful in education. In particular, it is emphasized that ChatGPT can help teachers to guide teachers, use existing materials effectively, and design student-specific activities. In addition, teachers also trusted the potential of ChatGPT to fill in their missing knowledge. However, some teachers were concerned about negative consequences such as technological dependency, decreased social skills, damage to the teacher-student relationship, and misinformation. These concerns provide an important discussion point on how the role of technology in education should be balanced. As a result, ChatGPT needs to be carefully considered in early childhood STEM education to understand and manage the balance between its potential benefits and the risks it may bring. This illustrates the various factors that need to be considered when determining the role of technology in education.

6 Conclusion and discussion

This study aims to examine the effectiveness of ChatGPT, which is used to overcome the difficulties encountered in early childhood STEM education, based on teachers' views. For this purpose, a special training program was prepared for early childhood teachers to ensure the successful integration of ChatGPT into STEM education. Teachers participated in this training program and carried out activities within the scope of sample STEM education integrated under the guidance of ChatGPT. Then, the teachers planned and implemented the ChatGPT-integrated STEM activities under the guidance of the researchers. In the last stage, they expressed their opinions about the effectiveness of ChatGPT in solving the problems encountered in early childhood STEM education. The data obtained were analyzed in detail to determine the emerging themes about the effective use of ChatGPT in overcoming the difficulties encountered in STEM activities.

The results of the study point to important views that ChatGPT can be used as an effective aid in material design to overcome the material shortage challenge that teachers face in STEM education. First of all, the shortage of materials that teachers face in STEM activities has been known as a prominent problem for a long time and this shortage can make the teaching process difficult (Çiftçi & Topçu, 2022; Wan et al., 2021; Yıldırım, 2021). However, the fact that ChatGPT provides teachers with ideas for material design with the materials at hand is considered as an important step in overcoming the difficulties. In addition, designing materials suitable for students' individual characteristics can make the learning process more effective and increase students' interest in STEM fields (Ferri & White, 2024; Mou, 2024; Ng et al., 2023). These advantages can enrich students' experiences in STEM fields in the classroom and enable them to learn more effectively (Rasul et al., 2023; Vasconcelos & Santos, 2023). These advantages of ChatGPT can also help teachers to prepare efficient and flexible materials with existing materials in STEM activities (Karaman & Goksu, 2024). Moreover, the experience of giving students a broad perspective of the materials may allow teachers to use their time more effectively (Al-Mughairi & Bhaskar, 2024; Gill et al., 2024). AI tools such as ChatGPT have significant potential to solve

the problem of lack of materials in early childhood STEM education. Such tools can reduce teachers' workload, provide students with a better STEM education, and make their learning experiences in the STEM field richer and more effective.

The results of the research indicate that the difficulties faced by teachers in STEM education have the potential to be overcome under the guidance of ChatGPT depending on their individual deficiencies. Early childhood teachers and pre-service teachers experience difficulties in the implementation of STEM education due to their lack of detailed knowledge in science, technology, engineering and mathematics (Campbell et al., 2018; Shernoff et al., 2015). Considering that the quality of education received by teachers has a significant impact on students' academic achievement (Ejiwale, 2013), it is of great importance to address these deficiencies in the planning and implementation of STEM education-based activities. The potential of ChatGPT to provide teachers with information about current developments in STEM and to provide opportunities for continuous development can be a valuable tool in the process of addressing these gaps (Elbanna & Armstrong, 2024; Yu, 2024). Teachers in this situation require enhanced and sustained training in STEM content knowledge and pedagogical strategies to improve their capacity to explain STEM concepts at appropriate developmental levels, choose suitable materials, facilitate STEM integration, and effectively manage time and classroom dynamics (Brenneman et al., 2019; EL-Deghaidy et al., 2017; Shernoff et al., 2015; Tao, 2019). By providing teachers with up-to-date information and guidance, AI-powered ChatGPT can enhance their ability to plan and implement in-class STEM activities more effectively, thus improving students' understanding of STEM subjects.

The results of the research identified the views that teachers should evaluate ChatGPT's individualization strategy suggestions to overcome the challenges related to students' individual differences that they face in STEM education. Providing students with tailored learning materials and activities through individualization strategies has the potential to increase students' engagement and achievement in STEM education (Adeyele, 2024; Aljermawi et al., 2024; Karaer et al., 2024; Salman et al., 2024). One of the major obstacles to the successful implementation of STEM education is designing activities that are appropriate for students' levels and, accordingly, attracting students' attention (Ramli et al., 2017). The main reason for this situation is the lack of a STEM education program specific to teachers and students (Wang et al., 2023). ChatGPT's individualization strategies can guide teachers in creating content that suits students' individual needs (Karaman & Goksu, 2024). This, in turn, can help students engage more effectively in STEM activities by increasing their interest level and participation (Adeyele, 2024; Karaer et al., 2024). On the other hand, providing materials tailored to students can help them be more successful in STEM subjects by taking into account their different learning styles and speeds. The individualization strategies offered by ChatGPT can contribute to teachers' more effective management of student-focused STEM education, thus enabling students to have a better learning experience.

According to the results of the study, ChatGPT's ability to provide personalized content, increase classroom interaction, and provide guidance can play an important role in overcoming the classroom management challenges teachers face in STEM education. ChatGPT's ability to provide teachers with ideas on designing person-

alized activities suitable for students, as well as providing guidance on classroom management, can provide teachers with the ability to manage more effectively in the classroom (Elbanna & Armstrong, 2024; Hashem et al., 2024). Time management, collaboration, and lack of time for teaching are among the challenges in the STEM education implementation process (Kiazai et al., 2020; Ramli et al., 2017; Shernoff et al., 2017). In addition, a study by Bal and Bedir (2021) pointed out that science and mathematics teachers experience difficulties in classroom management while implementing STEM education (Bal & Bedir, 2021). Teachers or pre-service teachers should undergo training on techniques to enhance their skills in managing the classroom and time effectively while implementing STEM education (Çiftçi & Topçu, 2022). Tools like ChatGPT can help teachers develop these skills. Thanks to the guidance and personalized content it provides, teachers can manage STEM education more effectively in the classroom. This, in turn, can enable students to better focus on STEM subjects and have a more productive learning experience.

The results of the study reveal that ChatGPT's ability to provide motivation-enhancing suggestions and guidance has an important potential in overcoming the difficulties related to student motivation problems faced by teachers in STEM education. It has been stated in the literature that low motivation is a frequently encountered problem in early childhood STEM education (Çiftçi & Topçu, 2022; Yıldırım, 2021). This problem is usually caused by not planning activities that are suitable for students' individual characteristics (Çiftçi & Topçu, 2022). Developing motivational strategies specific to students can positively affect the learning process (Dalgıç et al., 2024). One of the obstacles to the successful implementation of STEM education is the inability to design activities that are appropriate for students' levels and, accordingly, low motivation of students (Ramli et al., 2017). At this point, ChatGPT has the opportunity to guide students in planning activities according to their individual characteristics. ChatGPT seems to have significant potential to provide solutions to student motivation problems. With the guidance and motivational suggestions it provides, it can support teachers in planning student-oriented and effective STEM education and thus make students more motivated.

According to the results of the research, teachers have various opinions on evaluating the positive and negative effects of ChatGPT on students in STEM education. A number of positive effects of integrating ChatGPT into STEM activities were identified, such as increasing student engagement, supporting student creativity, promoting individualized learning, strengthening problem-solving skills, and providing interactive learning experiences. However, some teachers expressed concerns about possible negative effects. These concerns included technology addiction, decline in social skills, decreased teacher-student rapport, and inaccurate information. In addition, it has been emphasized in the literature that ChatGPT can produce false and fake information and that there are some doubts about its accuracy and reliability (Baidoo-Anu & Owusu Ansah, 2023; British University, Vietnam & Perkins, 2023; Jalil et al., 2023; King & chatGPT, 2023; Mogali, 2023; Szabo, 2023). In particular, the challenges related to accuracy and reliability that arise with the use of ChatGPT in education should be taken into account (Sallam, 2023). These challenges arise from the fact that ChatGPT may contain biased or erroneous information as it is trained on a large dataset, its knowledge may be limited, and it may not be updated with post-2021 data (Baidoo-Anu & Owusu Ansah, 2023; Gilson et al., 2022; Khan et al.,

2023). Therefore, it should be taken into account that responses may not always be accurate or reliable, especially on specialized topics and current events. Teachers and students should have sufficient knowledge and literacy when using AI tools such as ChatGPT and be alert to potential issues related to accuracy and reliability (Bower et al., 2024; Kolade et al., 2024; Ng et al., 2023; Yu, 2024). Along with the benefits that AI tools such as ChatGPT bring to learners, it is also important to pay attention to accuracy and reliability. Taking an informed approach to using this technology can reduce potential risks and make learning experiences safer and more effective.

Based on the research results, it was determined that AI-powered ChatGPT has the potential to offer disadvantaged students who face geographical or economic barriers the opportunity to support their learning. This potential can play an important role in increasing access to education and learning, achieving greater equity and supporting sustainable development goals. In particular, the potential to provide support tailored to individual learning needs can make ChatGPT an effective solution to overcome challenging situations and, accordingly, ChatGPT can be used as an alternative tool to mitigate the negative effects of challenging situations.

The COVID-19 pandemic has accelerated the use of digital technologies in education, leading to issues related to digitalization in schools, especially the lack of experience and low digital capacity in many schools, increasing inequalities and learning losses (Timotheou et al., 2023; Uğraş et al., 2023). Ng et al. (2023) stated that AI has gained popularity due to its potential to help students learn during the pandemic (Ng et al., 2023). Based on the research results, it was determined that AI-supported ChatGPT offers the opportunity to support the learning of disadvantaged students who face adversities or geographical or economic barriers during the pandemic. This potential can play an important role in increasing access to education to achieve greater equity and support sustainable development goals. In particular, the potential to provide support tailored to individual learning needs can make ChatGPT an effective solution to overcome challenges. Therefore, experts believe that ChatGPT can serve as a substitute tool to lessen the adverse impact of difficult circumstances. It is critical for teachers to have competencies appropriate to the post-modern era in order to meet the demands of twenty-first century education (Rahimi, 2024).

This study has some limitations. First, the small number of participants ($N=43$) in the study may limit the generalizability of the results. The limited number of participants can be attributed to time and resource constraints. We strongly recommend conducting future studies with larger and more diverse participant groups. In particular, including educators from various socioeconomic and cultural backgrounds may contribute to the generalizability and validity of the findings. Secondly, our study is based on teachers' opinions after the training they received before implementing ChatGPT in real classroom settings. This may not fully reflect the effects of ChatGPT in the real classroom environment. The limited time period of the research process prevented the use of ChatGPT in the classroom environment. Besides the training process, it would be important to integrate ChatGPT directly into the classroom environment and evaluate the long-term effects of this integration. Such an implementation would allow us to better understand the real-time experiences and reactions of teachers and students. We recommend future studies focus on ChatGPT's classroom use and its long-term effects.

6.1 Recommendations for future studies

This study focuses on the effectiveness of using ChatGPT in overcoming the difficulties encountered in early childhood STEM education according to teachers' views. In this study, it was applied to teachers who participated in the activities within the scope of STEM education developed by teachers with the support of ChatGPT. One of the limitations of this study is that these activities were not applied to children in early childhood. In future studies, activities within the scope of STEM education in which ChatGPT is integrated can be carried out directly with children. In this study, semi-structured interviews with teachers and researcher observations were conducted. In future studies, in addition to these data collection techniques, studies can be conducted by adding different data collection techniques.

Appendix 1: Semi-structured interview questions

- How do you think ChatGPT will contribute to you in the process of overcoming the lack of materials you encounter in STEM education?
- How do you think ChatGPT will contribute to the processes of overcoming the teacher's own deficiencies within the scope of STEM education?
- How do you think ChatGPT will contribute to you in the process of overcoming the problems related to the individual differences of your students you encounter in STEM education?
- How do you think ChatGPT will contribute to overcoming the classroom management problems you encounter during STEM activities?
- How do you think ChatGPT will contribute to overcoming student motivation problems you encounter in STEM education?
- What effect do you think ChatGPT will have on students in STEM activities?

Data availability The datasets generated and analyzed during the current study are not publicly available to preserve research participants' privacy but are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have no conflicts of interest.

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