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Research Article

Effects of STEM education on the academic success and social-emotional development of gifted students

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Abstract

STEM education, accepted as one of the most significant educational movements of recent years, is an approach that aims to educate students, including gifted students, in the disciplines of science, technology, engineering, and mathematics as a whole. This research aims to provide a general framework of the effect of STEM education on academic success and social-emotional development using the meta-synthesis method related to the work done for gifted students. The descriptive distribution of 28 studies that meet the criteria for inclusion in thematic meta-synthesis is given according to the data source of the publications. A critical examination of literature published from 2010 to 2020 identified combining and analyzing the results of research on STEM education in the field of gifted education. The view that STEM education positively affects gifted students' academic and social-emotional development has once again been proven through qualitative data. The findings of this study on STEM programs showed that attending a unique program can meet the needs of highly able students. When STEM education is viewed through the lens of the multifactor model, it can be said that it works to meet their academic, social, and emotional needs. While the literature focuses on how these needs are not met, it was refreshing to experience students with high learning potential who are mostly satisfied with their educational opportunities and social environment. Implications for STEM education on academic success and social-emotional development and suggestions for future research are discussed.

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Introduction

The systematic convergence of science, technology, engineering, and mathematics into an integrated STEM curriculum provides students a more extensive base of real-life learning skills (English & King, 2019; Fan et al., 2021). This convergence helps students learn STEM content through the application of the scientific method and the cycle of

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engineering design (MacFarlane, 2015; Margot & Kettler, 2019; Self, 2020). Being science and technology literate has become extremely important in both developed and developing countries. Work force and economic development policies encourage individuals to develop their cognitive and technical skills across multiple stages of acquiring knowledge, formal education, and applied training. These goals seek to raise new generations of children equipped with STEM concepts, open to innovations with an entrepreneurial spirit, and an ability to think creatively. To nurture and equip such a generation, requires an educational climate that gives students a sense of responsibility and encourages the development of their STEM self-efficacy. Quality STEM education allows students to explore and confronts mistakes while equipping them with technological knowledge from a young age (Ihrig et al., 2018; Gale et al., 2020).

Recently in science education, learning experiences have trended toward engineering and technology disciplines. As a result, students are gaining skills such as generating ideas and creative problem solving with depth and complexity (Johnson et al., 2020). In this way, scientific thinking and engineering practices provide students with opportunities to explore possible solutions to the environmental and social problems they face (Dailey et al., 2018; Dailey & Cotabish, 2016). Through practical activities, interactive discussions, independent work, and teamwork in the STEM process, students reach targeted learning goals, configure the newly acquired knowledge, and develop self-management and self-confidence skills. Students also gain research skills as they complete their projects, strengthen their relationships with peers and adults, and work in collaborative groups to see the positive effects of their work. In STEM education, meaningful and permanent learning occurs through integrated and applied knowledge and skills presented through a broadly structured research process, original questions, and carefully designed products and activities (Millar, 2020; Wilson, 2018).

Integrated STEM education has been widely advocated and implemented with students across all grade levels and ability ranges. While the effects of STEM education have been studied across geographic boundaries and educational systems (e.g., Aldemir & Kermani, 2017; Toran et al., 2020), less is known about the impact of STEM education on students identified and participating in gifted education. The purpose of this meta-synthesis study was to examine the impact of STEM education on gifted and talented student populations.

Conceptual Framework for Studying Gifted Education and STEM

Gifted and talented curriculum should be differentiated across four areas of learning design: course of study, curriculum standards, instructional models, and authentic engagement (Kettler, 2016). For students to achieve the domain-specific outcomes that constitute advanced performances, the curriculum needs to be intentionally altered and aligned at each of the four levels. A quality gifted education provides out-of-school services such as mentors, experts, and programs that develop the skills of students. Additionally, quality gifted education should foster academic development and provide behavioral strategies for gifted and talented students due to effective and stimulating learning experiences (NAGC, 2019). Gifted students need to have problem-solving opportunities to be able to adapt to real life (Reis & Renzulli, 2018). Gifted students must concentrate on their interests to develop research projects. The development of societies depends on the ability of gifted students to receive appropriate, timely education. To direct gifted students to real life, STEM education is one of the models applied in the education of gifted students, currently trending worldwide (Morris et al., 2019).

Recent national reports advocate preparing learners for careers in science, technology, engineering, and mathematics (President's Council of Advisors on Science and Technology, (PCAST, 2010). STEM education helps students in the United States see themselves as scientists, mathematicians, and individuals with capacity to pursue STEM careers. Moreover, students participating in rigorous educational programs have a better chance of pursuing STEM careers (Almarode et al., 2014; Yoon & Mann, 2017). Thus, STEM education has the potential to support gifted students through high-quality curriculum, career planning in STEM disciplines such as aerospace engineering, astronomy, biochemistry, statistics, psychology, and a focused pathway to prepare for increasingly rigorous educational opportunities (Bruce-Davis et al., 2014; Robinson et al., 2014; Sternberg, 2019).

Gifted students feel confined in schools with standard curriculums and teaching approaches for the typical student. Each has distinct talents, interests, obsessions, passions, and occasionally learning problems. Gifted children understand complex concepts quickly and acquire content more quickly and in detail than their classmates. They want more in-depth discussion. They understand and generalize ideas.

Educators have advocated modifying all three areas (disciplines of study are framed by emphasizing advanced content, higher-order thinking, processing, and products are developed, and learning experiences are created around significant concepts, issues, and themes that occur in real-world applications and theoretical understandings within and across disciplines) and developing an integrated curriculum model (ICM) for talented children. ICM helps gifted students develop their abilities and talents in their own manner and at their own speed (Van Tassel-Baska & Baska, 2021). ICM emphasizes big ideas, advanced material, critical thinking, real-world applications, and cross-disciplinary methods. ICM is aimed to accelerate learning quicker and deeper than standard curricula. It encourages critical thinking above repetition and memorization. It emphasizes multidisciplinary conceptual learning. Structuring, compacting, and accelerating are supported. It allows talented students to thrive in their own manner.

STEM in Gifted Education

STEM education is advocated for all learners, but STEM curriculum in gifted education should include a differentiated framework in order to contribute to the development of high ability learners (Johnson et al., 2020). The open-ended and inquiry-based approach of STEM learning tasks are ideal for creating a differentiated learning environment (Dailey et al., 2018; MacFarlane, 2015; Mun & Hertzog, 2018). Ideally, personalizing or customizing STEM education for talented students yields advanced learning trajectories that become more complex as it progresses. The theoretical model for STEM in gifted education includes both the principles of STEM integrated learning and the principles of gifted and talented curriculum. This merging of the two educational approaches yields a curriculum emphasizing the following: (a) advanced STEM content, (b) complex thinking with a STEM framework, and (c) conceptual understanding of STEM problems, theories, and ideas (Kettler, 2018).

Academic Success and Social-Emotional Development of Gifted Students

All students develop socio-emotionally from childhood to adulthood. Some disagreements remain whether identified gifted students develop similarly or dissimilarly from the non-identified peers. Fundamental to this issue is the theory of individual differences. Intelligence and academic potential are the chief traits on which gifted students differ from non-identified peers. The theory of individual differences states that there are covariate elements that will differ in individuals concurrent with the differences in intelligence and academic potential (Lubinski, 2000). Much of the research indicates that identified gifted students develop socially and emotionally quite similar to non-identified peers (Bracken & Brown, 2006; Cross et al., 2008; Wiley, 2020). However, there may be some ways that individual differences in high intelligence students corresponds with some social and emotional differences.

One potential area (domain) for differential development is self-concept. Gifted students tend to exhibit higher global self-concepts and higher perceived academic competencies than general education peers (Litster & Roberts, 2011; Sarouphim, 2011). When gifted students are accelerated academically, they demonstrate even higher levels of global self-concept (Hoogeveen et al., 2012). In other words, gifted students tend to be more self-aware than their peers and this greater awareness could benefit from differentiated STEM education.

Another area of potential differences is perfectionism. While the research suggests that gifted students are no more likely to develop maladaptive perfectionism, their experience with perfectionism may be qualitatively different (Margot & Rinn, 2016; Rice & Ray, 2018). Gifted students may more intensely concern themselves with small failures and experience academic pressures in some unique ways. Differentiated STEM education for gifted students could interact with their high cognitive ability and yield some effects related to the theory of perfectionism.

Positive and productive social, emotional, and academic development are typical goals of all types of education including STEM education and gifted education. Strength-based approaches to development define skills and competencies in each of the three areas (Aspen Institute, 2019). Typical examples of skills and competencies include the following. In cognitive development, students acquire the abilities to create objectives, plan future, endure, concentrate, and address these issues. In social and interpersonal development, students learn how to deal with social problems, settle disagreements, show respect for others, collaborate and work as part of a group, advocate for themselves, and take ownership of their own learning. In the area of emotional development, students learn to identify and control their emotions, comprehend the feelings and perspectives of others, display empathy, and deal with stress and setbacks (Allensworth et al., 2018). Thus, as we ask the question of whether STEM gifted education impacts the cognitive, social, and emotional development of students, these skills and abilities are examples of those potential outcomes.

Lack of Empirical Evidence

Though STEM education is often recommended for gifted students, gaps exist in the literature concerning its effect on the academic success and social-emotional development of gifted learners. The current study contributes to understanding the effect of STEM education on gifted students. This study also provides a potential framework for researchers for future studies within this conceptual space.

There are limited STEM education studies in connection with bright kids and there is no consensus among STEM stakeholders about what is the ideal STEM program for gifted students in schools (Mullet et al., 2018). In this respect, systematic literature reviews are important both for following the developments of scientific studies and determining associated trends. Besides, such studies are also essential to identify the problems arising in a field. In this study, we employ a meta-synthesis approach using qualitative data analysis techniques to make valid and trustworthy conceptual analyses (Finfgeld-Connett, 2018). In the meta-synthesis approach, the research team relies on textual narratives that describe and explain the findings of each study included in the synthesis rather than statistical analysis as would be used in meta-analyses.

Aim of Study

This study examined and synthesized primary research studies related to the effects of STEM on two major areas: the academic achievement of gifted students and social-emotional development of gifted students. The following research questions were answered.

- How does STEM education affect the academic success of gifted students?
- How does STEM education affect the social-emotional development of gifted students?

Method

We used a meta-synthesis research protocol to answer these two research questions. Meta-synthesis has been noted as a valuable analytic tool in social and health science disciplines (Hanes & Macaitis, 2012), and evidence synthesis was the primary goal of the study. In meta-synthesis, the research team uses qualitative analysis techniques to systematically review primary studies and generate synthesized results (Braun & Clarke, 2021; Finfgeld-Connett, 2018). Meta-synthesis begins with a position of objective idealism acknowledging that results exist and can be rationally and systematically synthesized (Ludvigsen et al., 2016). Within this tradition, our analytic processes involved classifying findings of primary studies and meta-summarizing those findings within established theoretical frameworks (Gough et al., 2017; Harden, 2010).

Screening Model

The table presents a rubric for assessing the quality of articles (see Table 1). A 5-point scale was applied to each article, with 1 being "poor" and 5 being "excellent" out of eight criteria.

The literature identification process is long and challenging. For the literature to be discovered, each research question needs to have descriptive, clear, and understandable information about the author, year, type of publication, and attachments of the studies that meet the inclusion and exclusion criteria presented in a table. The table contains the research codes, author, publication name, publication year, and theme code of the studies.

Studies included in thematic meta-synthesis contain some descriptive features related to the inclusion and exclusion criteria. The presentation of descriptive tables by the researcher is an approach that increases the reliability of the research. The source of the synthesis confirms the suitability of the research question with the data set. (Braun & Clarke, 2021; Finfgeld-Connett, 2018). In Table 2, the descriptive distribution of 28 studies that meet the criteria for inclusion in thematic meta-synthesis is given according to the data source of the publications.

The 28 studies consisted of 18 studies performed in the United States, and eight studies were non-USA (two studies in Australia, two studies in Turkey, one study in Taiwan, one study in China, one study in Israel, and one study in Netherland. Two studies were cross-cultural. One stud was performed in USA and Norway (Lange, 2018), and the other one was conducted in Spain, Ukraine, India, Singapore, Australia, Canada, and the USA (Haggerty, 2014).

Search Criteria

The inclusion criteria in the meta-synthesis include the following: time frame, databases, keywords, findings of the studies, and publication type (Borenstein et al., 2011). In the selection of primary studies for the analysis, the studies had to be published within in 2010 or later. Studies written in English were included. Qualitative studies were included. Quantitative studies, book chapters, and non-empirical studies were excluded. Those taking part in the study must have been students in elementary, middle, and high school, as well as students attending college. Any study with participants outside the K-12 and college-age groups was excluded from the study. As an example, Tay et al. (2018) and Margot and Kettler (2017) were removed from the present meta-synthesis review since they were conducted on teachers.

Table 1.
Meta-synthesis Rubric

Criterion	5: Excellent	4: Good	3: Average	2: Fair	1: Poor
Setting	Setting includes STEM education that improves academic achievement and fosters social-emotional development	Setting includes STEM education that contributes to academic achievement and social-emotional development.	Setting includes STEM education that attempts to foster academic achievement and social-emotional development.	Setting includes STEM education, academic achievement, and social-emotional development.	Setting does not include STEM education, academic achievement, and social-emotional development.
Methodology	All assertions and support conclusions are based on sufficient observed and measured phenomena and derives knowledge from actual experience.	Most assertions and conclusions are based on sufficient observed and measured phenomena and derives knowledge from actual experience.	Some assertions and conclusions are based on observed and measured phenomena and derives knowledge from actual experience.	Assertions and conclusions are based on observed and measured phenomena and derives knowledge from actual experience.	Assertions and conclusions are based only on observed and measured phenomena.
Addressing process	Addresses four or more processes stages of the STEM education.	Addresses at least three processes stages of the STEM education.	Addresses at least two processes stages of the STEM education.	Addresses at least one processes stages of the STEM education.	Fail to address any processes stages of the STEM education.
Compatibility	Research questions require a clear purpose, focus, setting, support, and processes.	To some degree, purpose, focus, setting, support, and processes can be relevant to research questions.	Some key factors require research questions.	Not directly relevant to research questions.	Does not apply to research questions.
Reporting	Sources for further reading are provided in the citations.	Citations that are thorough and accurate.	Citations that are complete entirety.	Citations that are not complete.	There are insufficient, incorrect, and/ or missing citations.
Setting	Setting includes STEM education that improves academic achievement and fosters social-emotional development	Setting includes STEM education that contributes to academic achievement and social-emotional development.	Setting includes STEM education that attempts to foster academic achievement and social-emotional development.	Setting includes STEM education, academic achievement, and social-emotional development.	Setting does not include STEM education, academic achievement, and social-emotional development.
Methodology	All assertions and support conclusions are based on sufficient observed and measured phenomena and derives knowledge from actual experience.	Most assertions and conclusions are based on sufficient observed and measured phenomena and derives knowledge from actual experience.	Some assertions and conclusions are based on observed and measured phenomena and derives knowledge from actual experience.	Assertions and conclusions are based on observed and measured phenomena and derives knowledge from actual experience.	Assertions and conclusions are based only on observed and measured phenomena.
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Compatibility	Research questions require a clear purpose, focus, setting, support, and processes.	To some degree, purpose, focus, setting, support, and processes can be relevant to research questions.	Some key factors require research questions.	Not directly relevant to research questions.	Does not apply to research questions.
Reporting	Sources for further reading are provided in the citations.	Citations that are thorough and accurate.	Citations that are complete entirety.	Citations that are not complete.	There are insufficient, incorrect, and/ or missing citations.

The studies included had to be published in sources indexed in ERIC, Google Scholar, or ProQuest databases. Keywords for the studies to be included are "gifted + STEM," "gifted + academic success," "gifted + social development."

Initially, 568 primary studies were identified using the search criteria. After eliminating duplicates and papers that met our exclusion protocols, a total of 28 primary studies were used for the analysis (see Figure 1).

Data Analysis

Meta-synthesis applies qualitative data analysis processes to systematically synthesize the results of multiple primary studies. Even when the primary studies yield quantitative results, the process of synthesis involves qualitative analysis within a post-positivist tradition. In this study, which was designed with the thematic meta-synthesis method, the data were analyzed and interpreted by following the steps suggested by Braun and Clarke (2021).

Familiarization With the Data: This includes reading the entire dataset several times to familiarize yourself with dataset. The purpose of this step is to find information relevant to the research questions. Transcribing data by hand can be beneficial for researchers as it allows them to gain a deeper understanding of the data. I first read each publication once before coding in this phase. Taking notes at this point was necessary during this first round of each study as it required 'active reading.' Rather than coding, I utilized this active reading to become familiar with the main topics addressed in each study. To recognize the data in this study, each of the documents included in the research was read one by one, and the first codes thought to be related to the research question were marked.

Table 2

Studies Included in Meta-synthesis

Author/Year	Topic	Source	Grade level	Country
Jen and Moon, 2015	Students in Taiwan who graduated from a self-contained STEM-specific program.	Gifted Child Quarterly	High School	Taiwan
Coleman,2016	Black men's real-life motivations for pursuing careers in science, technology, engineering, and math.	Illinois Mathematics Science Academy	High School	US
Tofel-Grehl and Callahan, 2014	Community characteristics of STEM high schools.	Gifted Child Quarterly	High School	US
Wu et al., 2019	STEM talent development program perspectives of students.	Journal of Advanced Academics	College	US
Rice et al., 2016	Exceptional students of color in historically black colleges and universities in STEM fields.	Journal of Research Initiatives	College	US
Morris et al., 2019	Improving the STEM education of gifted Australian children by using rural knowledge.	Research in Science Education	Middle School	Australia
Mullet et al., 2017	Gifted high school students' perceptions on their STEM education.	Journal of the Education of the Gifted	College	US
Karahan and Unal, 2019	Gifted students designing eco-friendly STEM projects.	Journal of Qualitative Research in Education	K-6	Turkey
Dai et al., 2015	Living and learning in a STEM program: the perspectives of first-year college students.	Gifted Child Quarterly	College	China
Dieker et al., 2012	Encouraging gifted students to pursue jobs in the STEM fields via the use of computer-based simulations and virtual reality.	Gifted Education International	K-6	US
Hoyle, 2018	Study of Rural African American Girls Attending a Specialized STEM High School for Gifted and Talented Students.	Dissertation	College	US
Gilson and Matthews, 2019	Advances in Education: The New Early College High School for Engineers.	Journal of Advanced Academics	High School	US
Flowers III and, Banda, 2019	Participation in advanced placement and advanced math and science courses by Black males with STEM aspirations.	Gifted Child Today	College	US
Mun and Hertzog, 2018	From performing arithmetic to thinking mathematically, teaching and learning in STEM enrichment spaces.	Roeper Review	K-6	US
Vlies, 2013	Talented Students in STEM Gifted Program: Their Future Careers	Thesis	High School	Netherland
Collins and Roberson, 2020	Gifted black males in a program share their experiences in developing their STEM identities and talents.	Gifted Child Today	K-12	US
Bruce-Davis et al., 2014	Administrators, instructors, and students at STEM high schools all have different views on how best to educate and learn.	Journal of Advanced Academics	High School	US
Alcantara, 2015	Institutional and informal communities of practice on STEM	Dissertation	High School	US
Alrajhi, 2020	Teaching STEM Students in an Honors Program Using Holistic Approaches	Dissertation	College	US
Zocher, 2020	Qualitative Perspectives on the Strange Trails of Persistence in STEM	Thesis	College	US
Islam, 2019	Perspectives on Practices and Challenges of Science Teaching	Dissertation	K-6	US
Albert, 2020	The Effect of STEM on gifted learners.	Dissertation	Middle School	US
Sahin and Yildirim, 2020	Determining how STEM education influences gifted and talented students' post-secondary opportunities	Malaysian Online Journal of Educational Sciences	Middle School	Turkey
Kohan-Mass et al, 2018	The gender gap in STEM subjects	Gifted Education International	High School	Israel

Stith, 2017	Evaluations of STEM-focused schools	Dissertation	High School	US
Lange, 2018	Educating high-potential children in Norway and the United States about STEM.	Thesis	High School	Norway, US
Burt, 2014	Self-efficacy and middle-school students' STEM course selections.	Dissertation	K-6	US
Haggerty, 2014	Qualitative research on secondary school STEM student projects	Dissertation	K-12	Spain.., US

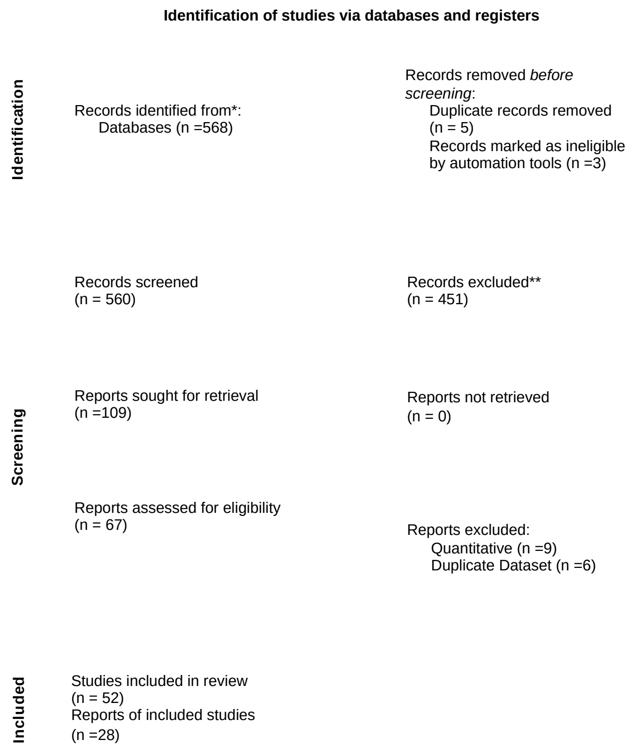

Figure 1

Flow Chart for the Inclusion and Exclusion Process of the Studies

Note. PRISMA flow diagram (McKenzie et al., 2020) of the article inclusion process

Generating Initial Codes: Themes are built from codes. Providing concise descriptive labels is used to describe or interpret data relevant to the study subjects. Researchers should spend equal time reviewing each of the data items in the dataset to establish themes. Codes should represent common elements within the research topic yet remain concise. Coding should occur for any data that could be used to answer the study questions. Through frequent code repetitions, the researcher can determine what codes are helpful for deciphering themes and which should be deleted.

Generating Themes: In this phase, data items to be coded are identified once all relevant items have been identified. From interpreting the meaning of individual data items within the dataset, we shift our focus to analyzing the meaning of aggregated meaning and significance of things within the dataset. It is then possible to review and examine the coded data to uncover ways in which different codes may be combined and thus form themes and sub-themes based on their shared meanings. Typically, a method of operating such would involve merging multiple codes into one to make it easier for the user to know what data they are viewing in a specific location. As the data is explored, it might just happen that one particular code should be considered representative of a specific theme or sub-theme that emerges in the data. Themes do not exist in the dataset which waits to be unveiled, however instead they reside within themselves. It is not merely sufficient that the researcher creates the relationship between the codes in a way that will help the researcher conceptualize the narrative of a given theme. Still, the researcher should also actively construct this relationship. In terms of importance or salience, codes and data items part of a particular theme do not determine how important it is (Braun & Clarke 2021).

Reviewing Potential Themes: The candidate themes are considered along with the coded data items. In the current stage, some candidate themes might not be as useful as interpretations of the data or will not provide data that address the research questions. Additional inconsistencies may exist in the code and/or data items related to these themes. Therefore, researchers should consider the following key questions when reviewing potential themes, as outlined by Braun and Clarke (2021).

Defining and Naming Themes: Researchers are required to investigate the thematic framework in-depth and present a detailed analysis. Several themes and sub-themes related to both the dataset and the research questions should be expressed in relation to both. The themes should differ, summarize the data, and present an internally consistent interpretation. There is, of course, the need to bring all these themes together in a coherent and lucid synthesis, consistent with the content of the dataset as well as relevant concerning the research questions. During this evaluation point, last-minute changes may be made to the themes' names.

Producing the Report: A qualitative researcher does not write up analysis after the research has been conducted, as traditionally the writer would do in quantitative research (Braun and Clarke, 2012). A recursive approach to reporting will be required here, as with previous phases. Throughout the analysis, Codes and themes are dynamic and ever-evolving, as does the write-up. During this phase, it should be documented changes with notes and maintain research throughout the entire project. In his report, the researcher would have begun writing before completing their thematic analysis. In phase six, the report would be finished and inspected thoroughly.

Creation of Main Codes

As seen in Table 3, to make comparisons and conversions between studies, the studies that comply with the inclusion and exclusion criteria, the title of the studies, the study's subject, purpose, results and appendixes are categorized and determine two main themes. A coding form has been developed. Coding form, (1) STEM education criteria for determining the academic achievement of gifted students; (2) Determination of the contribution of STEM education to the social-emotional development of gifted students and gifted students (3) study results and result evaluations. Coders extracted qualitative data from each study during the first phase of coding. After that, the author categorized each analysis and extracted data from approximately 20 variables showing the main characteristics of the studies. As part of the coding process, all data sharing similar attributes were considered as one subcategory, and the original extracted data were reclassified. For example, academic achievement is grouped into 6 sub-categories: "academic achievement test results, mats success, science success". Similarly, social sensory development had seven subcategories: "Self-awareness Attitude Satisfaction Social Relationship Self-perception Participation in activities Motivation". In total, 100 hours were spent coding all 28 studies, ranging from 300 to 600 minutes for each. After the preliminary coding was completed approximately eight months after the original coding, a recheck of the coding for intervention features and a plot of the study results ensured that coding had been done correctly.

Table 3

Codes of Meta-Synthesis

	Codes	
Categories	**A priori**	**Emergent**
Cognitive dimension Individual competencies and personal development Motivational skills development	Academic Success	-STEM's effect on academic success -Academic achievement -Test results -Math success -Science success -Attending school -Creative Thinking
Social, and affective development Autonomy	Social-Emotional Development	-STEM's effect on Social and Emotional -Self-awareness -Attitude -Satisfaction

	-Social relationship -Self-perception -Participation in activities -Motivation -Self esteem -Underachievement -Perseverance/Passion -Self-perception -Self-esteem -Self-efficacy -Self-confidence -Positive attitude -Satisfaction -Peer relationship -Relationship between teachers and students -Motivation -Interest -Enjoying and exciting learning environment

Coding

The coding of studies depends on the identification and classification of outcome variables (See Table 1). The current meta-synthesis is based on two types of results. The first was academic success. 18 of the 28 qualitative studies evaluated the effects of STEM education on 18 specific outcomes. These results included math, science score, and GPA. These results were then divided into five a priori codes during the article screening process (Academic achievement, test results, Math scores, Science scores, attending school). The 15 qualitative studies identified 30 specific outcomes in relation to social-emotional development. Each of these 30 specific outcomes was further coded into five a priori codes during the article screening process, which include: (1) Self-awareness Attitude Satisfaction Social Relationship Self-perception Participation in activities Motivation Self-esteem.

Developing Categories

After coding all the articles independently, explanatory information (research design, sample size), final codes, and potential categories and themes were organized into a table for each article. The final categories were (a) Cognitive dimension, (b) Individual competencies and personal development, (c) Motivational skills development, and (d) Social and affective development, (e) Autonomy. After the categories were created, article citations and data notes were examined. Potential themes were prepared independently in each category. Finally, categories and themes were jointly reviewed, defined, and named in the context of the research questions (Braun & Clarke et al., 2021; Gough et al., 2017).

Results

Academic Achievement and Social-Emotional Development Overview in Meta-Synthesis

In this meta-synthesis study, two common themes are academic success and social-emotional improvement. Studies investigating the effect of STEM education on academic achievement and social-emotional development of gifted learners were examined. The findings of this study on STEM programs showed that attending a unique program can meet the needs of highly able students. When STEM education is viewed through the lens of the multifactor model, it can be said that it works to meet their academic, social, and emotional needs. While the literature focuses on how these needs are not met, it was refreshing to experience students with high learning potential who are mostly satisfied with their educational opportunities and social environment. Analysis of responses of students, teachers, and parents from programs provides quality programs that aim to provide bright students with good education insight on how to meet their needs and give them an advantage for the future.

The findings of 28 studies met the final requirements (See Table 2). When STEM education is applied, it has been noticed that gifted students make progress in terms of acceleration and enrichment. It has also been found in studies that STEM education increases the motivation of gifted students and the ability of programs to meet their educational needs through challenging content suited to their higher abilities. Thanks to STEM education, highly skilled grouping and teacher support are mostly seen to support gifted students' social and emotional needs in the programs and contribute to the academic success and participation of students in these. Highly talented students developed a better social atmosphere through a substantial focus with their peers in similar groups, which facilitated making friendships. When it comes to the findings of gender, it is observed that STEM education has revealed the academic self-concept of female students appearing positively. Females feel more confident from an academic perspective. STEM education also helps to eliminate stress and anxiety for highly talented black female students.

Cognitive Dimension

Gifted students need enriched education to achieve their academic goals and develop socially and emotionally—two academic goals in English, Language, and Art (ELA) to write evidence-based claims and write claim-proof-reasoning statements in science. STEM education improves the reasoning skills of gifted students. Students participated in a STEM-based unit on stars and constellations throughout Albert's (2020) study, and students learned to write claim-proof-reasoning scientific statements. Before and after the unit, the participants conducted research that evaluated their ability to understand evidence-based claims in ELA, claim-evidence-reasoning statements in science, and the content of stars and constellations. Overall, students grew in all three areas. These results showed that writing claim-evidence-reasoning statements in STEM positively affected fifth-grade gifted students' ability to write evidence-based claims in ELA (Albert, 2020).

In Zocher's (2020) study, the aim was to provide social support and foster a sense of belonging for the twelve STEM students. The group was intended to be a social environment where students could talk about things that they could not otherwise find a place to discuss outside of STEM education settings, thereby developing the social dimensions of science identity. As can be seen from students' voices and echoed in study, there was a definite development of the group as a community from the beginning of the term to the end. After overcoming the issues of academic, and social-emotional learning, students found an area of trust and comfort where they could support each other, find common identities, and make meaningful friendships (Mullet et al., 2018; Jen & Moon, 2015). The activities proved particularly effective in achieving the goals of the group by allowing students the freedom to share themselves in an environment devoid of judgment and other restrictions found in traditional academic settings. Additionally, such conversations encourage meaningful reflections on gifted students' own individual journeys (Zocher, 2020).

Individual Competencies and Personal Development

In parallel with the interaction between the disciplines, the integration of engineering design processes into the lessons has been realized with bridges, simple machines, and various robotic studies, which were made using various materials within the scope of in-school STEM applications (Bruce-Davis et al., 2014; Burt, 2014; Flowers III & Banda, 2019). These studies enabled students to approach a problem that they might encounter in daily life more systematically and supported their collaborative work. It has been observed that the inclusion of engineering design processes in school lessons has helped students gain 21st-century skills such as generating innovative solutions, critical thinking, and conducting scientific research. In-class STEM activities were generally conducted in science classes (Burt, 2014; Flowers III & Banda, 2019; Mullet et al., 2018; Sahin & Yildirim, 2020). In these studies, conducted on gifted students, their views on STEM activities were positive. It is concluded that classroom activities are effective on scientific creativity and problem-solving processes. Out-of-school STEM practices were generally carried out in after-school activities, projects, and summer camps. The studies in which these activities were carried out concluded that out-of-school activities were practical for students. The studies in which robotic activities were carried out concluded that students' interest in engineering fields increased.

STEM applications improve academic success of students. In the study conducted by Mun & Hertzog (2018), researchers investigated the STEM application effect on gifted students. According to the results of the t-test in the analysis, it was observed that the students in the experimental group in which STEM education were applied had higher academic success and their orientation to STEM teaching compared to the students in the control group who did not experience STEM applications. In this case, it can be said that the application of STEM education is effective in increasing the STEM orientation of the students and their academic achievement in science. The effect of STEM education on students' academic achievement in study (Haggerty, 2014) on STEM education with gifted students, it has been seen that STEM applications are more successful in increasing students' academic success than non-STEM applications. In short, it shows that STEM applications are effective in improving the academic success of students at knowledge, comprehension, and application levels.

Teaching each student as an individual and allowing education to be tailored to what works best for each student is one of the 21st-century skills. The STEM education program meets their social-emotional needs through different strengths, such as the ease of developing friendships and their preference for group work (Alrajhi, 2020; Flowers III & Banda, 2019). Therefore, it can be said that STEM education programs meet the general needs of gifted students. To meet their needs, teachers and educators must be aware of the differences between students. Whether in a particular program or a regular classroom, the level of ability, interests, learning style, gender sensitivity, and speed are important factors to consider when providing tailored education to these students.

Motivational Skills Development

Interdisciplinary relationships within STEM education help students find innovative solutions to 21st-century problems. STEM education is understood to motivate gifted students and develop them academically, socially, and emotionally. In the studies about STEM education, it is observed that the motivation of highly able learners towards STEM has developed positively. Enough challenging tasks through a focus on STEM and enrichment may be the reason for this. Another motivating factor for gifted students is that STEM education also takes place outside of school (Alcantara, 2015; Islam, 2019; Mullet et al., 2018). While intrinsic and extrinsic motivation can explain why a student in a STEM education increases their motivation after they perform above their standards after participating in the program, this can also be explained by non-STEM domain-specific giftedness. However, loss of motivation must be taken seriously as this can lead to boredom, failure, and dropout. Since one female student in each program reported that she decreased her academic self-concept after participating in the programs, there were cases where motivation was closely linked to academic self-concept (Hoyle, 2018). While it can be said that students' perceptions about the use of their creativity in programs are mostly positive, different perceptions about creativity may affect their reactions (Alcantara, 2015; Bruce-Davis et al., 2014;).

Gifted and talented students prefer positive interactions with teachers, parents being supportive and satisfied STEM education, and STEM allowing students to be creative. It is seen that gifted students prefer group work in STEM programs compared to regular classes. Participating in the STEM programs helps students overcome some stress and allows them to excel. However, even if there is minimal contact between students and teachers or parents and teachers, parents have indicated satisfaction with the provision of STEM education for their children. The fact that parents are generally supportive increases the academic success of gifted students and contributes to their social-emotional development. This indicates how students' interest in STEM and the competitive educational environment in the US enables young students to choose their educational paths based on convenience and attractiveness, not their interest in the university (Alcantara, 2015; Kohan-Mass et al., 2018). While STEM education has managed to meet the needs of creativity, it has created a challenging environment for gifted students and motivated them for the future in STEM.

Social and Affective Development

Development Learning new things for pure learning pleasure is something that characterizes many students with high learning potential in intrinsic and extrinsic motivation. STEM education seems to increase differences in motivational interest for gifted groups. Suppose the intrinsic motivation that caused gifted students to participate in STEM education programs was triggered by other outcomes other than learning about STEM. In that case, they may be extrinsically motivated, which may explain their loss of motivation after participating in the program (Alcantara, 2015; Bruce-Davis et al., 2014; Mullet et al., 2018). This may also indicate that some of the gifted students of STEM education are just high achieving students. The reason for this high achievement; intrinsic motivation is a distinct feature in students with high learning potential. However, most people are driven by the mix of extrinsic and intrinsic motivation, and the type of motivation is context dependent. Furthermore, orientation and ambition for the future are characteristic of gifted students when talking about the future of STEM. As most students are motivated for a future in STEM, it seems that students have easier access to higher education and more likely experience intrinsic motivation. Gifted students may need to focus more on the future and consider the possible positive consequences of their education. Therefore, students participating in the program may be interested in STEM education that is more flexible than traditional education. Lange (2018) research showed that there were students with more extrinsic motivation in the technology program; this may be due to the increased focus on STEM education and career, higher pressure for higher education, and higher earnings.

Gifted children are individuals with higher-than-average intelligence or abilities. Understanding their needs in general due to their high-level cognitive capacities and meeting their needs that differ in time is significant. One of the factors in meeting their needs is related to the development of their social relations. Highly talented students often describe the peer group experience as very supportive in the STEM education program, mostly through finding positive relationships and interconnectivity. They also find that certain content is particularly useful in learning about each other's past experiences and travels to the university and beyond. Although less common, some students identify difficulties in the group related to time management, unpleasant content, and the lack of desire to share in a group setting (Moss-Everhart, 2020; Mullet et al., 2018; Zocher, 2020). Overall, many students describe STEM education as very useful during the focus group for gifted students. They also describe building diverse friendships, working partners, and an overall relaxed and supportive community, unlike other academic settings they had previously experienced. It is stated that students' sense of self and their science identities and self-efficacy is positively affected due to being in the group. As expected, students enter STEM program with various supports and challenges that affected their ability to continue (Chowdhury, 2016; Flowers III & Banda, 2019; Moss-Everhart, 2020).

Moreover, in STEM education, friends, peers, family, and educators are essential for gifted students' social, and affective development. A particular theme that emerges in STEM education is the importance of parent support. It is supported by previous literature emphasizing the relationship of such connections to student achievement (Alcantara, 2015; Flowers III & Banda, 2019 Stoeger et al., 2016). Factors are complex and often intertwined, such as the push and pull of self-regulation and family support. Often, when a student discusses internal discourse or feeling external influences, it changes for the better due to perseverance. Before starting a task, asking gifted students questions to explain the rules, talking about a plan to solve a problem, having them explore alternative problem-solving strategies, and helping to consider the consequences of the action before it begins builds perseverance. This situation clearly shows Bandura's claims that self-efficacy is extremely important in student development (Sloan, 2020). Gifted students' sense of self and identity are positively affected by STEM group work.

Autonomy

Gifted students highly value autonomy. The benefit of autonomy supports the successful effect of STEM education on giftedness (Gilson & Matthews, 2019; Mullet et al., 2018; Vlies, 2013). In practice, autonomy support includes giving the student a choice, encouraging them to take action, accepting their point of view, and limiting control over their actions. Respondents in this study indicate immense pleasure with the power of STEM education to create important careers and create unconventional opportunities for gifted students. Participants also express their relational ties to the cultural environment positively. For an individual to initiate an action, they must believe in their ability to perform the tasks necessary to obtain results successfully. STEM supports highly able students, keeps them determined, encourages them to continue working, and offers realistic role models, factors that increase motivation (Flowers III & Banda, 2019; Gilson & Matthews, 2019; Kohan-Mass et al., 2018). Thanks to the analysis carried out to address the research problems, it is observed that STEM education contributes to the social and emotional development of highly talented students. The results are meaningful since changing affective characteristics such as interest, attitude, and motivation is time-consuming. In addition, it also has been seen that perceptions towards STEM education generally center around science concepts.

Discussion

This main focus of this research is to examine the effects of STEM education or gifted students on their academic and socio-emotional development for metanalytic perspective. Talented students thrive in situations where difficulties are encountered, or personal interest topics are incorporated (Kettler, 2016). The actual results found in the subsets of science and engineering can perhaps be attributed to this project's nature. The curriculum requires hands-on activities where students use problem solving and creativity to move from one aspect of the project to another (Kim et al, 2016; Ozkan et al, 2015). In this study, which aims to evaluate the effect of STEM applications on the academic achievements of gifted students, their inquisitive learning skills perceptions, motivation towards science, permanent learning, and attitudes towards STEM, the results were examined following the research questions. The first research question of the study discussed how STEM education affects academic achievement on bright learners. A positive impact regarding academic success was found in the group exposed to STEM education compared to the group who received the regular curriculum. These findings show that STEM education practices increase academic achievement.

STEM Achievement

STEM enhances gifted and talented students in each discrete domain, including academic achievement. Considering the differences between the group in which STEM education was integrated and other groups, it is evident that STEM education has a positive effect on the teaching-learning environment, increasing academic success at knowledge, comprehension, and application levels of gifted students (Jen & Moon, 2015; Tofel-Grehl & Callahan, 2014). However, low achievement of gifted students results from inadequate services, improper placement, and a lack of attention given to gifted programs, particularly by school leaders (Steenbergen-Hu et al., 2020). Therefore, although STEM education has a positive effect on gifted learners, there can actually be a negative effect on academic achievement under certain circumstances. The studies also show that STEM integration increases the academic success of gifted students (Cotabish et al., 2013; Robinson et al., 2014; Hoyle, 2018; Islam, 2019). While only the results obtained for gifted students are presented (Robinson et al., 2014), the group results are both gifted and typical ability students (Cotabish et al., 2013). The results of both studies are that STEM practices improve students' academic success. The results obtained from the present study are in agreement.

Additionally, STEM activities positively affected their academic achievement development (Dieker et al., 2012; Hoyle, 2018; Sahin & Yildirim, 2020). Further, activity evaluation forms to analyze activities of gifted students determined that their academic success improved as a result of STEM integration (Gilson & Matthews, 2019). Gifted secondary school students studying in a STEM program based on virtual and simulated environments impact academic achievement positively (Gilson & Mattews, 2019). An extra-curricular, school-based STEM talent development program for economically disadvantaged rural students increased the academic success of students (Hoyle, 2018; Morris et al., 2019).

With an integration of STEM and gifted education, learners have access to the development of many critical skills needed in today’s society. The fact that the students participating in STEM education see math and science practically and integrated with engineering and technology has changed their perspective. The education of gifted individuals is of great importance in terms of scientific and technological research and development studies. The activities are based on science and mathematics achievements and require engineering skills (Hoyle, 2018). The design-based learning method could effectively help teach challenging basic concepts in science courses and increase awareness about engineering among students (Coleman, 2016). Students' ability to integrate mathematical operations into the product creation stage and their abilities to use materials efficiently increased after such activities. Students improved their engineering design processes with STEM activities for elementary science students (Gilson & Matthews, 2019; Islam, 2019). The students' ability to create new and original products can be explained by the fact that they do not have anxiety to perform a certain way. This helps to draw a tighter connection between creativity and lack of anxiety. It can also be said that the engineering design skills of the students have improved significantly. Talented students are seen to be very involved in STEM measurements (Haggerty, 2014). They also claimed that STEM practices greatly helped gifted students build positive attitudes towards engineering and that positive attitudes are mainly towards engineering and then science. STEM integration has generated changes in many schools' approaches to learning, including an increase in making learning with fun and meaningful by incorporating problem-solving, critical thinking, concept teaching, strategy development, goal-setting, and non-distraction teaching, suitable for individual and group work.

STEM-related Courses

Another aspect of the integration of STEM education is the increase in positive behavior towards the lessons. The effect of STEM integration on students' perceptions and attitudes regarding STEM discipline areas are positive (Karahan and Unal, 2019). They worked with 17 gifted students and examined the project-based learning activity integrated with STEM. Before and after the event, questionnaires and semi-structured interviews were conducted to measure the attitudes of the students towards STEM. It has been concluded from the survey results that there are serious changes in students' attitudes towards engineering. Most of the students stated that STEM education is important in both engineering and science fields. Integrating STEM into project-based learning can allow students to learn by understanding and affect students' perspectives in their future career research and choices. They found that their perceptions and attitudes about STEM discipline areas developed due to the implementation of STEM activities and inquiry-based activities. As a result of attitude and perception tests applied, they determined a positive development in engineering, career, and technology. STEM education and engineering practices contributed to gifted and talented students' academic, social, and emotional development (Moss-Everhart, 2020) and improve middle school gifted students' awareness of engineering (Gilson & Matthews, 2019). STEM education's most significant benefit is an increase in attitude toward science and an improvement in motivation and interest in science subjects.

Integrating STEM contributes to gifted learners' positive interest and attitude toward the subjects. Gifted students have positive attitudes towards STEM education (Jeanpierre and Hallett-Njuguna, 2014). The conclusion that the activities implemented within the scope of this study have positive attitudes towards STEM education can be reached from the observation notes of the researcher-practitioner teacher. Special programs, including STEM activities, should be prepared for gifted students, and should be included in the programs developed for talented students (Bruce-Davis et al., 2014; Lange, 2018). These events include asking questions for science and defining engineering problems, developing, and using models, planning and conducting research, analyzing data, using mathematics and numerical thinking, creating explanations for science and designing engineering solutions, obtaining information, evaluating, and submitting. Thus, getting gifted students involved in STEM education results in improved interest and attitude. The effects of STEM integration on students' attitudes, feelings, and thoughts towards learning coding are considerable (Islam, 2019). After the integration their thoughts that they would have difficulty in coding changed. Besides, it was determined that students found coding easy and enjoyable. STEM activities improve students' attitudes towards science and their scientific process skills (Collins and Roberson, 2020). In addition to this, students have established optimistic attitudes towards STEM, the most important transition in education throughout the 21st century.

STEM applications cause a statistically significant increase in the motivation of gifted students towards the lesson. When the literature is reviewed, many studies show that STEM applications have an essential effect on increasing gifted students' motivation (Alrajhi, 2020; Heggerty, 2014; Hoyle, 2018; Gilson & Matthews, 2019; Stith, 2017). The impact of STEM programs on the motivation of students and found a positive effect (Morris et al., 2019). increase students' interest and motivation (Rice et al., 2016). Many other studies also show that STEM applications do positively affect attitudes (Karahan & Unal, 2019; Vlies, 2013; Wu et al., 2019). Based on this result, it can be noticed that these integrations have a beneficial impact on the attitude of bright kids towards STEM. Furthermore, STEM based science teaching is an effective method for students to learn science subjects. Such design-based activities increase gifted students' motivation towards science learning (Dai et al., 2015; Lange, 2018; Stith, 2017). In these studies, the design activities carried out within the STEM application framework increased both the desire of highly able learners to participate in science classes and their desire and motivation towards science learning. As a result of the observations made by the researcher within the framework of STEM-based science teaching, it was seen that the design-based STEM activities developed the communication, collaboration, critical thinking, and psychomotor skills of gifted and talented students. It also supported self-directed learning.

Additionally, STEM education encourages students to cooperate and helps them develop their communication skills. Students can learn from each other in the process of cooperation and communication between them (Vlies, 2013). It can be considered that the difficulties encountered during the implementation of design-based STEM activities with gifted and talented students in the classroom include difficulty in group work, limitations arising from the perfectionist approach of gifted students, lack of equipment, lack of technological equipment, and time limitation. Since many gifted and talented students think that their projects or activities should be perfect, they may not be satisfied with what they have done and may experience low motivation and demoralization. Because STEM education improves collaboration and communication between gifted students, it can reduce these negative consequences.

Implications for Practice

Educational equality involves considering the level of understanding, individual differences, and readiness of each individual in providing education. STEM education for gifted students should be planned based on the needs of gifted students. To contribute to the self-perception development of gifted students, students' opinions should also be considered in the planning of education and decision-making. The most appropriate STEM education strategy should be determined according to the needs of gifted students as individuals. STEM education has a flexible structure in the integration process, which makes it easy to tailor learning to student needs. The training program planned should be adapted during the process, considering this advantage of STEM education. The key question for educators is not whether gifted students should be differentiated, but rather, how this process will be carried out. Level-based STEM education practices should be carried out at natural transition points, such as the beginning of the school year of term. Problems with STEM education are often due to incomplete or inadequate planning. In context, the careful planning of the whole process, including the stages of the process, the personnel to be assigned, the applications to be carried out, the family meetings to be held, and the limits' determination, will facilitate the implementation. Engineering has started to find more place in education with the increasing prevalence of STEM education approach. With design-based learning, it is aimed that gifted students encounter design problems that can be the context for learning science concepts and skills. The construction and testing of real devices will allow students to experience science and test their concepts, discovering errors and gaps in their knowledge (NGSS, 2013). For the successful implementation of STEM education in an education system, compulsory and elective engineering courses must be included in the program. Instructors who are equipped to conduct these courses must be assigned. Although engineering courses are sufficient at some K-12 levels, they cannot be useful since they are not integrated. At some levels, there are not enough engineering courses. Additional engineering courses should be given at these levels. The number of hours of existing engineering courses should be increased; not only should it be increased, but interdisciplinary cooperation should be established between courses.

Limitations

It is necessary to assess the present meta-synthesis in light of its limitations from a variety of viewpoints. As previously stated, the main restriction is due to the generally poor quality of the research, which is the primary drawback. Therefore, the results of this meta-synthesis should be taken with care in light of this information. We should successfully address the academic achievement and social-sensory development of gifted people in the future. Furthermore, to address issues such as selection and detection biases, the accuracy of intervention practices, and the assessment of impacts – to improve the quality of evidence for the effects of interventions, increasing efforts by individual researchers are required.

Conclusion

Compared to previous research, the present meta-synthesis provides a complete, in-depth, and more nuanced picture of the effects of STEM education on the gifted in terms of academic performance and social-sensory development. He argues that more significant efforts in STEM education may be required to convert an increased desire for studying into actual improvements in academic performance. A differentiated curriculum may be the most effective method of teaching them to improve the performance of talented children and support their social-emotional development. Qualitative data help enhance our understanding of underachievement among gifted individuals (Steenbergen-Hu et al., 2020). Given the many reasons and routes for failure among talented kids, effective treatments may need the development of customized methods for each particular student.

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