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Editors

Ayşe Ceren **ATMACA AKSOY**

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PREFACE

Education plays a central role in the development of individuals and society, and in fulfilling this role, the intersection of two critical disciplines—Science Education and Psychological Counseling and Guidance Discipline is becoming increasingly important. This book aims to provide an interdisciplinary perspective that brings together current research and innovative approaches in these two fundamental fields. In today's world, students are expected not only to be equipped with academic knowledge but also to possess 21st-century skills such as critical thinking, problem-solving, and psychological resilience. While science education undertakes the mission of understanding nature and developing scientific literacy, counseling and guidance discipline makes vital contributions to this process by supporting students' social-emotional development, offering stress management strategies, and promoting inclusive learning environments. This book consists of carefully selected chapters representing current scientific research from both fields. The primary aim of the book is to provide academics, teachers, counselors, and graduate students in related fields with a rich and comprehensive resource that transcends the boundaries of their own disciplines. It is hoped that these studies will both shed light on future research in the fields of science and psychological counseling and guidance discipline and provide practitioners with practical, evidence-based information that they can use in their classrooms and counseling processes. We thank all the authors and researchers who contributed to this work and hope that it will make a valuable contribution to the literature of educational sciences.

December, 2025

Editors

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INTRODUCTION

People typically encounter various difficulties throughout their lives, ranging from daily challenges to major life events (Fletcher and Sarkar, 2013). In this case, people who are constantly exposed to stress-inducing factors today need to cope with these difficulties and stressors in order to maintain their well-being in their lives (Karairmak and Cetinkaya, 2011). It can be said that psychological resilience is one of the most important factors in coping with these difficulties and stressors. According to Begun (1993), individuals with high psychological resilience possess the qualities and resources to cope with challenging life events. Teachers face many stress factors stemming from their personal lives, such as problems in their relationships, domestic conflicts and financial difficulties in addition to the challenges arising from their professional lives and they struggle with these life difficulties. It is believed that these life difficulties and stress factors experienced by teachers directly affect the educational environment and the education and training services provided. It can be said that psychological resilience is one of the most important factors that can be used to overcome these difficulties.

Newman (2005) defined, psychological resilience as the ability of individuals to adapt in the face of tragedy, trauma, distress, hardship and ongoing significant life stressors. Luthar (2005), on the other hand defined psychological resilience as a process or phenomenon that reflects a partially positive adaptation despite significant trauma and risk experiences. Another important factor that helps teachers cope with the challenges they face is life skills. The World Health Organization (WHO, 1997) defines life skills as positive and adaptable abilities that enable individuals to effectively cope with the challenges and demands of daily life. Kolburan and Tosun (2011) define life skills as the abilities that individuals need to acquire in order to positively

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develop during periods of growth and change. The effective acquisition and application of life skills can influence how we feel about ourselves and others and equally influence how others perceive us. Life skills contribute positively to our sense of self-efficacy, self-confidence, and self-esteem. Therefore, life skills play an important role in improving our mental well-being. Improved mental well-being contributes to our motivation to care for ourselves and others, the prevention of mental disorders, and the prevention of health and behavioral problems (WHO, 1997). Life skills play a significant role in current educational programs. The increase in the number of individuals receiving education in recent years, the growing complexity of life and the increased need for skilled individuals have contributed to the prominence of life skills in the education and training process (Mutluer, 2013). Considering the importance of life skills in the education and training process, teachers must also possess certain life skills in order for students to develop the life skills they will use when facing difficulties (Bolat and Balaman, 2017). This is because teachers' possession of life skills such as empathy, self-awareness, interpersonal relationships, and effective communication contributes both to improving the quality of education and to increasing teachers' job satisfaction in their profession (Yuksel-Sahin, 2008; Bolat and Balaman, 2017; Bursalioglu, 2019). In a world that is constantly changing, evolving, and becoming increasingly complex, it is important to raise individuals with high psychological resilience and life skills (Gomleksiz and Demiralp, 2012; Mutluer, 2013). In order for teachers to play an effective role in raising these individuals and to manage this process well, it is important to examine teachers' psychological resilience and life skills.

In this study, firstly conceptual and theoretical information about the concepts of psychological resilience and life skills will be included, then the findings of the studies in the literature on psychological resilience and life skills of teachers will be examined and the predictors of psychological resilience and life skills will be evaluated in the light of these findings.

Resilience

Theoretical Perspectives on Psychological Resilience

People encounter various difficult situations throughout their lives and strive to cope with these circumstances. In today's world, where people are constantly confronted with stressful elements, the extent to which they can successfully cope with the stress they encounter in order to maintain their well-being in their lives is becoming increasingly important (Karairmak and Cetinkaya, 2011). Many researchers who have studied children facing these life challenges have observed that some children are still able to succeed and overcome these significant difficulties when they reach adulthood (Masten, 2001; Oz and Yilmaz, 2009). This led researchers to propose the concept of psychological resilience.

The word “resilience,” when viewed in its literal sense means “return to the previous state,” “rebound,” and “the power to recover,” according to the Oxford English Dictionary. metaphorically, it describes how an individual may lose some of their strength and abilities in the face of negative experiences, may be adversely affected by these negative experiences, but can then recover and return to their previous level of functioning (Garmezy, 1993). When looking at the concept of psychological resilience as a definition, one encounters many definitions. Looking at some of these definitions, Newman (2005) defines psychological resilience as the ability of individuals to adapt in the face of tragedy, trauma, distress, hardship, and ongoing significant life stressors. Luthar (2005), on the other hand, defines psychological resilience as a process or phenomenon that reflects a partially positive adaptation despite significant trauma and risk experiences. Karairmak (2006) defines psychological resilience as the adaptive ability an individual develops in response to adverse circumstances in their life, through the interaction of risk factors and protective factors. Beyond these definitions, the concept of psychological resilience has acquired multiple meanings in various contexts (Bonanno, Romero, & Klein, 2015). For example, psychological resilience has been defined as a global process related to the development and maintenance of healthy adaptation (Egeland, Carlson, & Sroufe, 1993); as a positive outcome following difficulties experienced by an individual (Masten, 2007); as a trait or aspect of personality (Smith et al., 2008); and comprehensively as a set of resources, characteristics, and capacities (Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2008).

When examining definitions of psychological resilience, it is noteworthy that these definitions converge on three common points. These are:

a) The risks and/or difficulties experienced by the individual

b) The individual's coping with difficulties and subsequent adaptation,

c) Protective factors affecting the individual's psychological resilience (Gizir, 2007).

Psychological resilience has gained increasing importance in both theoretical and practical fields since its inclusion in scientific literature in the second half of the twentieth century (Luthar, 2006). Developmental psychologists, in particular, have long focused on the concept of psychological resilience, defined as “a process in which individuals demonstrate positive adaptation in the face of significant difficulties or traumatic experiences” (Luthar et al., 2000). The general aim of these researchers focusing on the concept of psychological resilience has been to identify protective factors that can mitigate the negative effects of adverse life conditions and subsequently uncover the underlying mechanisms based on these identified relationships (Luthar and Cicchetti, 2000; Masten, 2001).

There is no single characteristic defined as psychological resilience; rather, there are many behaviors and actions associated with psychological resilience (Newman, 2005). Maintaining good relationships, having an optimistic outlook on the world, keeping events in perspective, setting goals and taking steps to achieve them, and having self-confidence are all related in some way to psychological resilience (Luthar et al., 2000).

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Current research and theories view psychological resilience as a multidimensional construct that includes not only the skills that enable individuals to cope well with difficulties and traumatic events, but also structural variables such as personality and temperament (Campbell-Sills, Cohan, & Stein, 2006). Therefore, one person's strategy for developing psychological resilience is unlikely to be the same as another's (Newman, 2005). At the same time, individuals with high psychological resilience are seen to possess personal characteristics and social competencies resulting from a combination of genetic and environmental factors (Begun, 1993; Karairmak, 2006; Hosoglu et al., 2018). From this perspective, psychological resilience can be described as an individualized process dependent on the individual's strengths, skills, and experience (Newman, 2005). These individual differences in psychological resilience are of great importance in understanding how individuals cope with daily stress and eliminate these stress factors (Ong, Bergeman, Bisconti, & Wallace, 2006).

People with high psychological resilience possess the qualities and resources necessary to cope with challenging lives (Begun, 1993). Research on psychological resilience has shown that individuals with high psychological resilience have high self-esteem (Guloğlu and Karairmak, 2010; Karairmak and Cetinkaya, 2011; Arslan, 2015; Kara, 2020; Ozdemir and Adiguzel, 2021). At the same time, it has been observed that these individuals are better at using problem-solving coping strategies in the face of daily difficulties (Terzi, 2008). Research has also revealed that individuals with high levels of psychological resilience also have high levels of self-efficacy (Terzi, 2008; Arslan, 2015; Arslan and Balkis, 2016; Bektas, 2018; Kılıc, Mammadov, Kochan, and Aypay, 2020; Dogan, 2020; Kara, 2020). With these qualities and resources, individuals with high psychological resilience have been found to have greater life satisfaction (Alibekiroglu, Akbas, Ates, and Kırdok, 2018; Bektas, 2018) and higher levels of happiness (Altuntas and Genc, 2020; Dogan and Yavuz, 2020; Ulukan, 2020). When examining the relationship between psychological resilience and COVID-19, which has had a major impact in our country and around the world and has plunged the entire world into a pandemic, it has been observed that individuals with low psychological resilience have been more affected by this process and have developed anxiety (Celebi, 2020).

Risk Factors in Psychological Resilience

The difficulties, disasters, and negative life experiences that an individual may encounter in their life emerge as risk factors in leading a healthy life and demonstrating good psychological resilience (Karairmak, 2006). Durlak (1998) defines risk factors as variables that increase the likelihood of a negative life event occurring in the future; these variables may be demographic or social variables, and some are more adaptable and modifiable than others. Gizir (2007) states that risk factors may include socio-cultural, biological, genetic, and demographic characteristics or conditions.

Among risk factors, low socioeconomic status is highlighted as the primary risk factor because it is often combined with other risk factors such as low-status parental occupation, low maternal education, extended family, and ethnic minority status (Luthar and Zigler, 1991). To illustrate this situation, children living in a low socioeconomic status and poor environment are more likely to become ill and unable to attend school, have low school performance, experience developmental delays, and develop mental health disorders (Sapolsky, 2005). Other risk factors that have long-term negative consequences on individuals include emotional, physical, and sexual abuse (Margolin and Vickerman, 2007); neglect, lack of communication, mental or physical disability, peer pressure, lack of parental support, parents with mental illness, parental divorce or separation, natural disasters, and wars (Durlak, 1998; Luthar, 2006). These risk factors have a multiplicative effect on risk when they occur in combination (Rutter, 1979, cited in Winders, 2014). As an example of this situation, research conducted by Rennie and Dolan (2010) shows that there is a significant correlation between the number of behavioral problems exhibited by a child and the number of risk factors in their life.

Research on psychological resilience, when examined, reveals that despite addressing numerous risk factors, it is generally categorized under three distinct headings: individual, familial, and environmental (Balci, 2018).

Table 2.1 *Psychological Resilience Risk Factors*

Risk Factors		
Individual Risk Factors	**Familial Risk Factors**	**Environmental Risk Factors**
Premature Birth (Masten and Reed, 2002)	Abuse (Luthar, 2006)	Unemployment and Migration (Agaibi and Wilson, 2005)
Insecure Attachment (Roche, Runtz, and Hunter, 1999)	Physical, Emotional, and Sexual Abuse (Luthar, 2006)	Minority Communities (Spencer-Rodgers and Colins, 2006)
Low Self-Esteem (Rutter, 1987)	Poverty (Lynch and Cicchetti, 1998)	Social Violence (O'Donnell, Schwab-Stone, and Muyeed, 2002)
Low Self-Control (Rutter, 1987)	Parental Mental Illness (Lynch and Cicchetti, 1998)	War (Masten and Coatsworth, 1998)
Antisocial and Disruptive Behaviors (Rutter, 1987)	Parental Conflict (Lynch and Cicchetti, 1998)	Natural Disasters (Masten and Reed, 2002)
Ineffective Coping Methods for Life Difficulties (Rutter, 1987)	Low Socioeconomic Status (Lynch and Cicchetti, 1998)	

Protective Factors in Psychological Resilience

Research on psychological resilience indicates that individuals require quality care, good learning opportunities, adequate nutrition, and family support to ensure the positive development of cognitive, social, and self-control skills during early childhood (Masten and Gewirtz, 2006). Luthar (2006) defines these factors, which we call protective factors, as factors that positively modify the negative effects of risk. Individuals with strong psychological resilience can continue to show resilience in the face of adversity as their basic protective skills continue to develop (Masten and Gewirtz, 2006).

Psychological resilience, which is used by individuals to cope with difficulties, is influenced by internal and external protective factors. An individual's personal characteristics can be cited as examples of internal protective factors, while social support can be cited as an example of external protective factors. At the same time, these internal and external protective factors not only influence how easily an individual adapts to difficulties, but also positively influence the rate at which difficulties arise in their life (Karairmak, 2006).

When examining studies on protective factors in psychological resilience, it is observed that some researchers divide protective factors into two groups: individual (internal) and environmental (external) factors (Terzi, 2008). Some researchers (Benard, 1991; Masten and Coatsworth, 1998), however, divide them into three groups: individual personality traits or temperament, family characteristics or resources, and resources outside the family.

Table 2 *Protective Factors in Psychological Resilience*

Protective Factors		
Individual Protective Factors	**Family Protective Factors**	**Environmental Protective Factors**
Empathy (Luthar et al., 2000) Good Communication Skills (Garmezy, 1991) Good Problem-Solving Skills (Sapienza and Masten, 2011) High Self-Control (Shonkoff and Philips, 2000) A Clear Purpose for the Future (Sapienza and Masten, 2011) High Intelligence (Masten, 2001). Self-Confidence, Self-Esteem, Self-Efficacy (Karaırmak, 2006) High Intellectual Capacity Humor (Karaırmak, 2006	Secure Attachment (Winders, 2014) Encouraging Family Support (Luthar, 2006) A Good Relationship with Parents Based on Support and Affection (Rutter, 1987) Productive Role Gained by the Child Within the Family (Werner, 2000) Religion or Spirituality (Winders, 2014)	Good Relationships with Adults (Luthar, 2006) School Activities (Benard, 1991) Role Model Relationships with Teachers (Werner, 2000) Participation in Academic Activities Inside or Outside the Classroom (Winders, 2014) Supportive Community (Benard, 1991) Accessibility to Health Systems (Masten and Reed, 2002) Effective Emergency Services (112) (Masten and Reed, 2002).

Life Skills

Theoretical Perspectives on Life Skills

It can be said that life skills occupy an important place in the programs currently being implemented. The increase in the number of individuals receiving education in recent years, the fact that life is becoming more complex every day, and the growing need for skilled individuals have contributed to the prominence of life skills in the education and training process. In addition, the increase in communication both within and outside society and the emergence of different ways of accessing information are thought to have brought skills related to information literacy to the fore. In democratic societies, skills such as analytical and critical thinking and the ability to fulfill responsibilities have come to the fore for the sustainability of democracy (Mutluer, 2013).

When examining the definition of life skills, it is evident that there are different definitions. Curtiss and Warren (1973) defined life skills as problem-solving behaviors that are clearly defined and used appropriately and responsibly in the management of individual tasks. The WHO (1997), on the other hand, defined them as positive and adaptable abilities that enable individuals to effectively cope with the challenges and demands of daily life. Finally, Kolburan and Tosun (2011) expressed life skills as the abilities that a person must acquire in order to positively achieve the period of development and change in which they find themselves.

Life skills help individuals translate their interests, attitudes, and values into real abilities, answering the questions “What should I do?” and “How should I do it?” Life skills can be described as the abilities that enable individuals to behave in a healthy manner when given the scope and opportunity to do something. At the same time, life skills are not abilities that are a cure-all for every problem. In addition to these abilities, other factors such as social support, cultural and environmental factors also have an impact on people (WHO, 1997).

Fully understanding life skills can help individuals develop and maintain their life balance by adapting to the natural rhythm of the universe. Life skills can be described as one of the sources for understanding and possessing positive attitudes in the face of the demands and challenges of daily life, rather than acquiring knowledge about the secrets of life. The fundamental purpose of life skills is to empower and develop people to cope with all aspects of life (Kar, 2011)

The effective acquisition and application of life skills can influence how we feel about ourselves and others, and can equally influence how others perceive us. Life skills can contribute positively to our perceptions of self-efficacy, self-confidence, and self-esteem. Therefore, life skills are considered to play an important role in improving our mental well-being. Improved mental well-being contributes to our motivation to care for ourselves and others, the prevention of mental disorders, and the prevention of health and behavioral problems (WHO, 1997).

Life skills play an important role in enabling individuals to express themselves and successfully manage their lives in the complex society in which they live (Hamdona, 2007). However, with the changes occurring in many cultures and lifestyles, there has been a significant increase in the acceptance that many young people are not sufficiently equipped with the life skills that will help them cope with increasing demands and stress (WHO, 1997). Therefore, it is believed that teachers should possess certain life skills in order for students to develop their life skills in the school environment (Bolat and Balaman, 2017).

Classification of Life Skills

The number of skills referred to as life skills is quite high. The definitions and nature of life skills vary from culture to culture and environment to environment. Beyond these, when looking at life skills, it is seen that there are a number of basic skills for improving the health and well-being of adolescents and children. These are:

- Decision-making skills
- Problem-solving skills
- Creative thinking skills
- Critical thinking skills
- Effective communication skills

Since education is a process of shaping individuals and preparing them for life, and considering that teachers have a significant impact on individuals' lives and personalities, it is important that those who practice the teaching profession possess the aforementioned life skills to a greater extent than those in other professions.

Studies on Predictors of Psychological Resilience

O'Donnell et al. (2002) sought to statistically examine the dimensions of psychological resilience in children exposed to or witnessing social violence and in children not exposed to social violence, and to investigate the longitudinal relationship between psychological resilience and protective factors. The sample group for the study consisted of 2600 students in the sixth, eighth, and tenth grades. The results of the study revealed that parental support was a strong predictor of psychological resilience in the areas of self-efficacy, substance abuse, depression, and school abuse. However, as grade level increased, the predictive power of parental support decreased, while that of school support increased. Both parental and school support were found to predict psychological well-being at a higher rate in students who were not exposed to violence compared to those who were. At the same time, it was observed that in students exposed to violence, the predictive power of school support on psychological well-being shifted to peer support. It was revealed that school bullying and peer substance use negatively affected psychological well-being in all three groups: those exposed to violence, those who witnessed it, and those who did not.

Buckner, Mezzacappa and Beardslee (2003) conducted a study with 155 youth between the ages of 8 and 17 and their mothers, focusing on the self-control variable and examining the characteristics that distinguish youth with high psychological resilience from others. Analyses revealed that youth with high psychological resilience also had significantly higher levels of self-control and self-esteem. Furthermore, youth with low psychological resilience reported more negative and stressful life events. They also reported more life difficulties and higher rates of abuse. It was also found that mothers of youth with high psychological resilience monitored and controlled their children more.

Campbell-Sills et al. (2006) examined the relationship between psychological resilience and personality, coping, and psychiatric symptoms in young adults. The first part of the study examined the relationship between psychological resilience and personality. When examining the relationship between the five-factor personality structure and psychological resilience, a strong inverse relationship was found between psychological resilience and neuroticism, and a strong positive relationship was found between the extraversion and conscientiousness factors. Subsequently, the relationship between psychological resilience and coping was examined, and it was found that both task-focused coping and emotion-focused coping predicted psychological resilience. Additionally, it was found that retrospective reports of emotional neglect in childhood mitigated the relationship between current psychiatric symptoms. Finally, it was confirmed that individuals who reported relatively high levels of emotional neglect in childhood also experienced higher psychiatric symptoms if their current psychological resilience scores were low. Conversely, individuals who experienced significant emotional neglect but had high psychological resilience scores were found to have the lowest levels of psychiatric symptoms.

Steinhardt and Dolbier (2008) implemented a psychological resilience enhancement psychoeducation program to increase psychological resilience, coping strategies, and protective factors, as well as to reduce symptomatology (depressive symptoms, negative affect, perceived stress). The study sample consisted of 57 university students, comprising an experimental group of 30 and a control group of 27. The experimental group received four 2-hour psychoeducational intervention sessions per week. Measurements were taken for both the experimental and control groups before and after the intervention. The analyses revealed that the experimental group had significantly higher psychological resilience scores, more effective coping strategies, higher protective factor scores, and lower symptomatology scores.

In his study conducted with 264 university students, Terzi (2008) sought to examine the extent to which internal protective factors (self-efficacy, problem-solving-oriented coping, optimism) predict the psychological resilience of university students. The results of the study showed a positive and significant relationship between internal protective factors and psychological resilience, indicating that internal protective factors predict psychological resilience. In Arslan's (2015) study with 476 adolescents, Arslan and Balkis's (2016) study with 331 adolescents, Bektas's (2018) study with 835 married individuals, Kılıc, Mammadov, Kochan, and Aypay (2020) with 569 university students, Dogan (2020) with 406 school counselors, and finally Kara (2020) with 304 teachers also found a positive and significant relationship between psychological resilience level and self-efficacy level.

Guloğlu and Karairmak (2010) conducted a study with 410 university students, examining psychological resilience and self-esteem as predictors of loneliness. The results revealed a negative relationship between psychological resilience and loneliness, and a positive relationship between self-esteem and loneliness. A similar study was conducted in subsequent years by Karairmak and Cetinkaya (2011). In this study, with a sample group consisting of 362 earthquake victims who experienced the 1999 earthquake, the effect of experiential focus and self-esteem on psychological resilience was examined. The results of the study revealed a negative relationship between psychological resilience and locus of control, and a positive relationship between psychological resilience and self-esteem. Furthermore, this study showed that positive and negative emotions predicted psychological resilience.

In Ozer's (2013) study with 766 university students, the students' psychological resilience levels were examined in terms of the Five Factor Personality Traits and Emotional Intelligence Personality Traits. The results of the study showed that there was a positive correlation between students' psychological resilience levels and emotional intelligence, specifically the sub-dimensions of self-control, well-being, emotionality, and sociability. The same study found a negative relationship between university students' psychological resilience levels and neuroticism, and a positive relationship between psychological.

In a study conducted by Alibekiroglu et al. (2018) with 405 university students, the mediating role of self-understanding in the relationship between university students' life satisfaction and psychological resilience levels was examined. The analyses revealed that as university students' levels of self-understanding and life satisfaction increased, their psychological resilience levels also increased significantly. Furthermore, self-understanding was found to partially mediate the relationship between psychological well-being and life satisfaction. Another study on life satisfaction was conducted by Bektas (2018). Similar to the previous study, the study involving 835 married individuals found a positive and significant relationship between individuals' psychological well-being levels and life satisfaction.

Altuntas and Genc (2020), conducted study with 409 teachers, the relationship between teachers' psychological resilience levels and happiness levels was examined. The results of the study showed a positive and significant relationship between psychological resilience and happiness. Parallel to this study, Dogan and Yavuz (2020) conducted a study with 968 adults and found a positive and significant relationship between psychological resilience and happiness. In a similar study conducted by Ulukan (2020), a positive and significant relationship was found between the happiness and psychological resilience levels of the sample group consisting of 336 teachers.

Kara (2020) conducted a study with 304 teachers working at various educational levels to compare teachers' psychological resilience levels with their self-esteem, self-efficacy beliefs, and decision-making styles. The analyses revealed that male teachers participating in the study had higher psychological resilience scores than female teachers. Another finding was that teachers working in elementary, middle, and high schools had higher psychological resilience scores than teachers working in preschool. In the correlational analysis conducted in the study, significant positive correlations were found between teachers' psychological resilience scores and the subdimensions of self-efficacy belief. Similarly, significant correlations were found between teachers' psychological resilience scores and the subdimensions of decision-making styles.

When examining studies that assess teachers' psychological resilience in terms of sociodemographic variables, different results emerge. When examining whether teachers' psychological resilience levels differ based on gender, the studies by Hosoğlu et al. (2018) and Kara (2020) found that male teachers' psychological resilience scores were higher than those of female teachers, and a significant difference was observed. In contrast, the study by Bozgeyikli and Sat (2014) revealed the opposite situation, with female teachers scoring higher on psychological resilience than male teachers. In addition to these studies, Ulukan (2020) found that teachers' psychological resilience scores did not differ according to gender.

Studies examining whether psychological resilience scores differ based on parental attitudes have also yielded varying results. Ozer (2013) found that university students' psychological resilience levels differed significantly based on parental attitudes, with students from families exhibiting democratic attitudes having higher psychological resilience scores. On the other hand, Hosoğlu et al. (2018) found that teachers' psychological resilience scores did not differ significantly according to parental attitudes.

When the literature is examined, there are many research findings indicating that psychological resilience differs according to gender. A review of the relevant literature reveals multiple studies indicating that men's psychological resilience levels are higher than women's (Bahadir, 2009; Dogan and Yavuz, 2020; Hirani, Lasiuk, and Hegadoren, 2016; Hosoglu et al., 2018; Kilic et al., 2020; Kara, 2020; Sezgin, 2016). In the studies conducted by Hosoglu et al. (2018) and Kara (2020), the mean psychological resilience scores of male teacher participants were significantly higher than those of female teacher participants. Furthermore, in the research conducted by Dervisoğullari (2020) with faculty members of education faculties, the average psychological resilience scores of male faculty members were higher than those of female faculty members. In addition, the literature indicates that women have higher levels of psychological resilience than men (Hunter and Chandler, 1999; Oktan, Odaci, and Berber-Celik, 2014; Bozgeyikli and Sat, 2014) and that there is no significant difference (Terzi, 2008; Ozer, 2013, Ulukan, 2020; Guzel, 2021). Dogan and Yavuz (2020) attribute this difference in favor of men to cultural factors, stating that men are still raised to be strong and given more responsibility today, which positively affects individuals' psychological resilience. The male gender role is associated with responsibilities such as not giving up, not being unemployed, the expectation of providing for the family, being strong, and being wealthy (Ruxton, 2004). In this situation, it can be said that men, in particular, act in line with society's expectations, striving to fight problems and remain strong in the face of difficulties.

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When examining studies that investigate the relationship between marital status and psychological resilience, Bozgeyikli and Sat (2014) found that married teachers had higher levels of psychological resilience than female teachers. In the study conducted by Özdemir and Adıguzel (2021) with healthcare workers, it was also observed that married individuals had higher psychological well-being scores than single individuals. Cetin (2019)'s study with teachers also yielded similar results, showing that married teachers had higher psychological resilience levels than single teachers. Furthermore, Akgun (2021)'s study with preschool teachers showed that married teachers had higher average psychological resilience scores than single teachers. The data revealed in the research shows that married individuals have higher levels of psychological resilience than single individuals, which may be the result of the healthy relationships they have established with their spouses.

Positive and supportive relationships are one of the environmental protective factors in psychological resilience (Karairmak, 2006, Winders, 2014). Based on this, we can consider a healthy marriage as one of the environmental protective factors. Married individuals, in particular, have greater access to social support than single individuals (Ross, Mirowsky, & Goldsteen, 1990). Furthermore, research shows that marriage contributes to individuals' well-being (Lamb, Lee, & DeMarris, 2003). Based on this, it can be said that married individuals establishing positive and supportive relationships with their spouses contributes to their higher psychological resilience by enabling them to be more resilient in the face of difficulties.

When reviewing the literature on the relationship between the level of education at which the task is performed and psychological resilience, Cetin (2019)'s study with teachers showed that teachers' levels of psychological resilience did not differ significantly according to the level of education at which the task was performed. Similarly, Dogan (2020)'s study with school psychological counselors yielded similar results, showing no significant differences. Another study is Pakis (2020)'s study with teachers. This study also found that teachers' psychological resilience scores did not differ according to the school level. Finally, Ozkapu's (2019) study with school counselors also yielded results parallel to the research findings, showing no significant difference. The fact that teachers' psychological resilience levels did not differ significantly according to school level may be due to the regional context of the study. At the same time, since each school level has its own challenges, it is thought that teachers experience similar difficulties and that this situation affects their psychological resilience in a similar way.

When examining studies that investigate the relationship between perceived parental attitudes and psychological resilience, it is seen that psychological resilience in adults does not differ according to parental attitudes. Arslan (2018)'s research with university students revealed that university students' psychological resilience levels did not differ significantly according to perceived parental attitudes. Another study conducted by Dilmac-Pinar (2020) with nursing students yielded similar results, showing that the psychological resilience scores of nursing students did not differ significantly according to perceived parental attitudes. When examining the literature, psychological resilience scores show significant differences according to parental attitudes, particularly in studies conducted with children and adolescents (Gunduz-Algünerhan, 2017; Yildirim, 2019) , while studies conducted with adults show no significant difference (Arslan, 2018; Dilmac-Pinar, 2020). Based on this, it is thought that individuals who experienced negative parental attitudes during childhood have high psychological resilience scores in adulthood due to the influence of both individual protective factors and environmental protective factors. At the same time, it is thought that the fact that many of the adult individuals have established a new family with their spouses and have become independent from their parents is a factor in the lack of a significant difference.

Looking at the overall picture of the domestic and international studies mentioned in the previous sections on psychological resilience and providing a brief summary, psychological resilience is seen to have a positive relationship with many positive personality traits that facilitate individuals' adaptation to life and help them achieve good mental health, such as self-esteem, happiness, self-control, well-being, self-efficacy, life satisfaction, effective communication, and problem-focused coping strategies. On the other hand, it has been observed to be negatively related to negative life events such as depression and anxiety, which adversely affect a person's life. When examining studies that investigate psychological resilience according to sociodemographic variables, it is seen that there are studies that support each other according to gender, marital status, school level, and perceived parental attitudes, as well as studies that produce different results.

When examining the studies in general, some discrepancies and inconsistencies are evident in the findings regarding whether teachers' psychological resilience levels vary by gender, marital status, perceived parental attitudes, and level of education. These differing results may be due to cultural differences and individuals' differing values, thoughts, and perceptions regarding these variables. Furthermore, life and experiential differences may have contributed to these inconsistent results.

Research on protective factors for psychological resilience has identified empathy, good communication skills, high self-control, high intelligence, secure attachment, family support, good relationships with parents, good peer relationships, and a supportive community as protective factors for psychological resilience. Research on risk factors for psychological resilience has identified factors such as premature birth, insecure attachment, low self-esteem, low self-control, antisocial behavior, abuse by family members, exposure to abuse, poverty, parental conflict, unemployment, natural disasters, and war as risk factors for psychological resilience. Based on all these studies, it is thought that psychological resilience provides significant support to individuals in coping with life's difficulties and negative life events. Furthermore, it can be said that psychological resilience is a protective trait for people who face many stressors in their lives.

Research on Predictors of Life Skills

Ahmadi Gatab, Shayan, Tazangi, and Taheri (2011) conducted a study to examine the relationship between life skills and quality of life levels among students studying at Payame Noor University in Iran. The study involved 210 students studying at Payame Noor University. The results of the study showed that as university students' life skills increased, their quality of life also increased.

Boysak (2020) conducted a study with 456 classroom teachers to examine their views on life skills from a multi-variable perspective. The analyses conducted in the study revealed that the life skills levels of the participating classroom teachers were generally high. Furthermore, while classroom teachers considered themselves competent in the areas of communication, creative and critical thinking skills, they perceived themselves as less competent in coping with stress and controlling their emotions compared to other areas. Additionally, the life skills scores of male classroom teachers participating in the study were significantly higher than those of female teachers. Analysis conducted to determine the source of this difference revealed that male classroom teachers scored significantly higher than female classroom teachers on the sub-dimension of “emotional and stress management skills.”

Yakar (2020) conducted a study to examine the life skills of university students studying in the Child Development Department. The sample group for this study consisted of 259 university students studying in this department. The analyses revealed that the life skills scores of the university students participating in the study were generally at a medium to high level. When examining the life skills scores according to the students' grade levels, a significant difference was observed in the decision-making and problem-solving subscale and the communication and interpersonal relationships subscale. Upon examining this significant difference, it was observed that first-year students received lower scores than fourth-year students. When the students' life skills levels were examined in terms of the location where they spent their childhood, it was observed that students who spent their childhood in a town had higher scores in coping with emotions and stress than students who spent their childhood in a village or city. Finally, when examined according to the educational level of the parents, it was found that students with parents who had a bachelor's degree had significantly higher life skills scores than others.

When examining the domestic and international studies mentioned in previous sections on life skills, it is observed that life skills have a negative relationship with negative situations and behaviors such as depression, anxiety, problematic behavior, aggression, and alcohol use. Furthermore, life skills have been seen to increase an individual's quality of life and satisfaction. Based on all these studies, it is thought that life skills positively affect individuals' mental health by bringing order and satisfaction to their lives. It is also expected that these skills will help individuals cope with life's difficulties and indirectly have a positive effect on their psychological well-being.

It can be said that the fact that life skill levels are generally higher in men than in women is due to the value given to the male gender in society and family, and that men are supported to take more responsibility and gain experience in life. In addition, the increase in experience and awareness of individuals in parallel with the increase in education level and age may have contributed to the increase in life skills.

Studies on The Relationship Between Psychological Resilience and Life Skills

When examining the literature on the relationship between teachers' psychological resilience levels and the coping with emotions and stress sub-dimension of life skills, Ozkan (2019)'s study with high school students revealed a low level of positive correlation between coping with stress and psychological resilience. Similarly, Mil's (2021) research with sports science students and Timisi's (2021) research with students preparing for university entrance exams revealed positive correlations between students' psychological resilience levels and stress coping levels. Sadeghi (2021)'s research with adults from Iran and Turkey yielded similar results, revealing a moderately positive correlation between participants' psychological resilience levels and stress coping levels. Aydin (2010)'s research with university students also revealed a positive relationship between emotional awareness and psychological resilience.

When looking at the studies examining the relationship between teachers' psychological resilience levels and empathy and self-awareness skills, which are life skill sub-dimensions, Aydin (2010) found a positive relationship between students' empathy levels and psychological resilience levels in his study with university students. Similarly, in Toplu (2017)'s study with adolescents, a positive and significant relationship was found between empathy and psychological resilience. Another study supporting the results was conducted by Akduman, Karahan, and Solmaz (2018) with university students, and similar results revealed a positive relationship between empathy and psychological resilience. There are also international studies finding positive relationships between empathy and psychological resilience (Baek, Yang, and Chou, 2021; Haramati and Weissinger, 2015; Smith and Hollinger-Smith, 2015). In the study conducted by Harmanci, Ocalp, and Bozgoz (2019) with young adults, a positive and significant relationship was found between emotional self-awareness and psychological resilience. In addition, there are studies in foreign literature showing that self-awareness positively affects psychological resilience (Masten, 1999; Olsson, Bond, Burns, Vella-Brodrick, & Sawyer, 2003).

When the literature is examined on the relationship between psychological resilience and the sub-dimensions of decision-making and problem-solving skills, which are sub-dimensions of life skills, Durmus (2016) found a positive significant relationship between students' problem-solving skills and psychological resilience, and problem-solving skills predicted psychological resilience scores. Similarly, in S. Kaya (2019)'s study with elite basketball players, it was concluded that as students' problem-solving skills increased, their psychological resilience levels increased. Unal (2021)'s study revealed that as problem-solving skills of families with disabled individuals increased, their psychological resilience scores increased. In the study conducted by Yondem and

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Bahtiyar (2016) with adolescents, a positive significant relationship emerged between planned problem solving and psychological resilience. When looking at the foreign literature, a study conducted by Sagone, De Caroli, Falanga, and Indiana (2020) with adolescents found that adolescents who perceived their problem-solving skills as high had higher psychological resilience scores than other adolescents. Other foreign studies have found positive and significant relationships between psychological resilience and problem-solving skills (Carmeli, Levi, & Peccei, 2021; Li, Eschenauer, & Yang, 2013; Li, Eschenauer, & Persoud, 2018). Regarding decision-making skills, a study conducted by Aydın (2019) with high school students revealed a negative and significant relationship between decision-making difficulties and psychological resilience.

People need to make sound decisions in the face of the many problems they face daily (Deniz, 2004; Kokdemir, 2003). Therefore, having decision-making skills helps individuals solve the problems they encounter (Deniz, 2004). Problem-solving skills, similar to decision-making skills, involve coping constructively with the problems we encounter in our lives.

When looking at the studies examining the relationship between teachers' psychological resilience levels and the life skill sub-dimensions of communication and interpersonal skills, a moderately positive relationship was found between controlling relationships and psychological resilience in the study conducted by Aydin (2010) with university students, and a moderately positive relationship was found between communication skills and psychological resilience in the study conducted by Akduman, Karahan, and Solmaz (2018) with university students. In the study conducted by Choi and Yoo (2014) with parents of children with Down syndrome, it was observed that as the participants' communication skill scores increased, their tension and stress scores decreased. In addition, Garmezy (1987) stated that effective communication for the family constitutes one of the main protective factors of psychological resilience.

When looking at the resilience circle model developed by Henderson and Milstein (1996), one of the main components of the "reducing environmental risk factors" section on the right side of the circle is the item "teaching life skills." In this study, life skills are considered an important concept both in terms of their relationship with psychological resilience and in terms of their significant predictive value of psychological resilience. In another model of psychological resilience, the Benard model, it is stated that some of the characteristics acquired by individuals with high psychological resilience include empathy, good communication skills, problem-solving, and decision-making skills (Benard, 1991). These characteristics, as stated in Benard's (1991) model, constitute three of the sub-dimensions of life skills.

In studies examining the relationship between psychological resilience and coping with stress, similar results have been obtained in different sample groups, revealing a positive and significant relationship between psychological resilience and coping with stress (Kaya, 2019; Mil 2021; Ozkan, 2019; Sadeghi, 2021; Timisi, 2021). In Durmus (2016)'s study examining the relationship between psychological resilience and coping with stress, it was concluded that university students' problem-solving skills are one of the important predictors of psychological resilience. In Metzl's (2009) study with adults, parallel results were obtained, and although there was a positive relationship between creative thinking skills and psychological resilience, it was found that creative thinking skills did not predict psychological resilience. When we look at the studies examining the relationships between life skills and psychological resilience, there are studies that reveal that life skills have positive effects on psychological resilience (Huang et al., 2020; Sagone & Indiana, 2017).

A review of the studies revealed moderate correlations between teachers' psychological resilience levels and the life skills sub-dimensions of stress coping skills, self-awareness skills, problem-solving skills, and interpersonal communication skills. In short, significant positive correlations emerged between teachers' psychological resilience levels and all life skills sub-dimensions and total scores. Having a high level of healthy and supportive relationships, stress coping, and problem-solving skills positively impacts individuals' psychological resilience.

Teachers face numerous stressors and challenges in their work environment and personal lives, and after experiencing these challenges, they are forced to adapt to life and the current situation. In this adaptation process, the teacher's level of psychological resilience determines the speed and quality of this adaptation. It can be argued that the protective factors possessed by an individual are particularly important in the face of these challenges. In this regard, possessing life skills is one of the most important protective factors for psychological resilience in the face of these challenges.

Conclusion

Throughout their lives, people face many challenges, ranging from major life events to daily difficulties (Fletcher and Sarkar, 2013). Today, it is becoming increasingly important for people who are constantly exposed to stressors to be able to successfully cope with the stress they encounter in order to maintain their well-being (Karairmak and Cetinkaya, 2011). Teachers face many stressors and difficulties in their work environment and personal lives, and as a result of these difficulties, they are forced to adapt to life and the current situation.

It is believed that the psychological resilience of the teacher determines the speed and quality of this adaptation process. It can be said that the protective factors possessed by the individual are of great importance, especially in the face of these difficulties. Life skills are expected to be one of the important protective factors of psychological well-being in the face of these difficulties.

Teachers' high psychological resilience is important not only for their personal mental health but also for their ability to communicate effectively with students and create a healthy school and classroom environment. For this reason a comprehensive life skills psychoeducation program can be developed to strengthen teachers' life skills and indirectly contribute positively to their psychological resilience, and applications can be made to teachers through training for this service.

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TEACHER COMPETENCIES FOR THE INCLUSIVE EDUCATION OF STUDENTS WITH AUTISM SPECTRUM DISORDER

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INTRODUCTION

Inclusive education means much more than students sharing the same physical environment; it requires a flexible and planned process in which teaching can be adapted to students' individual learning needs. This is clearly stated in the Salamanca Statement (1994) published by the United Nations Educational, Scientific and Cultural Organisation (UNESCO). The Declaration advocates that teaching and classroom arrangements should be reshaped according to the developmental and educational needs of the student, rather than expecting the student to adapt to the existing system. When considering students with autism spectrum disorder (ASD), the quality of inclusive education is determined by the teacher's subject knowledge, their ability to translate teaching decisions into concrete classroom practice, and their pedagogical approach that takes into account the student's learning profile. Therefore, the teacher is positioned as a central professional actor in the design and implementation of the learning process in the classroom.

The primary aim of this chapter is to delineate the fundamental areas of competency that teachers must possess to support students diagnosed with ASD in inclusive education settings; to examine the reflection of these competencies in classroom practices; and to analyse the challenges encountered in practice in the light of current research.

Theoretical Background

Inclusive education refers not only to the physical presence of students diagnosed with OSB in mainstream classrooms, but also to meeting their educational and social needs through qualified teaching strategies. Lynch and Irvine (2009) define this process as the integrated transfer of evidence-based best practices into the classroom environment. In this context, inclusion is not limited to the student's presence in the classroom but is defined by the quality of the instruction provided.

The most critical factor determining this quality in inclusive educational environments is the teacher. The heterogeneous nature of autism spectrum disorder (ASD) and the developmental characteristics that vary in each child make the teacher's role even more complex. Low and colleagues (2020) emphasise that success in the inclusive education of students with ASD is directly related to the teacher's level of knowledge and the attitudes they develop. Teachers' positive attitudes towards ASD and their perceptions of competence are the key predictors of the success of classroom practices (Koçak, 2025).

In line with these requirements, teacher competencies necessitate design within a multi-layered theoretical framework rather than a unidimensional structure. Bukvić (2014) models teacher competence in inclusive education as a composite of knowledge, skills, and values/attitudes components. In this context, *knowledge* refers to the teacher's command of the nature of ASD and relevant legislation; *skills* refer to the capacity to implement teaching methods; and *attitude* refers to their beliefs regarding inclusive education. Current research also reveals that the dimensions of knowledge, skills, and attitude exist in a dynamic interaction with one another (Pang et al., 2025). Therefore, in this chapter, teacher competencies will be discussed through a holistic perspective based on these three fundamental areas of competence.

Inclusive Teaching Competencies for ASD

The ability of students diagnosed with ASD to be academically and socially successful in inclusive education settings depends to a large extent on the teacher's competencies in planning, executing, and monitoring this complex process. The literature reveals that teacher competencies are not limited to general pedagogical knowledge alone; rather, they must be addressed within the framework of three fundamental components comprising ASD-specific professional knowledge, practical skills, and attitudes/values.

Professional Knowledge

The foundation of an inclusive classroom is laid by the teacher's accurate understanding of the nature of ASD. Toran et al. (2016) state that teachers' levels of readiness regarding autism are directly correlated with the theoretical knowledge they possess; and that in cases where the level of knowledge is insufficient, they experience hesitation in practice. In this regard, as stated by Koçak (2025), the teacher must internalise the concept of the "spectrum" and must know that every student exhibits a heterogeneous profile in terms of social communication and sensory sensitivities. Knowing only the diagnostic features is not sufficient. Wei and Yasin (2017) emphasise that an effective teacher must possess a fund of knowledge updated through continuous professional development regarding legal rights, educational assessment processes, and evidence-based practices.

Professional Skill and Practice

The transformation of knowledge into classroom practice and tangible improvements in student outcomes is accepted as the most visible dimension of teacher competence. While Lynch and Irvine (2009) define this dimension as the "integration of best practices", Finch et al. (2013) emphasise that teachers working in general education classrooms must possess skills specifically in three areas:

1. *Behaviour Management:* Instead of viewing problem behaviours solely as disciplinary issues, focusing on understanding the need underlying the behaviour and implementing non-punitive, preventive classroom management strategies,

2. *Instructional and Environmental Arrangements:* Supporting classroom instructions and workspaces with visual materials to facilitate the student with ASD's independent movement and participation in the lesson.

Attitudes, Values, and Collaboration

However strong technical skills may be, the sustainability of inclusive education is shaped by the teacher's conviction. In their study conducted with pre-service teachers, Talib and Paulson (2015) demonstrated that teachers possessing a high perception of self-efficacy regarding ASD are more persistent and successful in inclusive practices. However, a positive attitude is not confined solely to in-class processes. Sakarneh et al. (2023), in their research grounded in the parents' perspective, revealed that the most critical socio-educational competence for teachers is "effective communication and collaboration with the family". Similarly, Koçak (2025) emphasises that a teacher profile possessing cultural sensitivity and viewing the family as an "expert partner" accelerates the student's development. In this context, a teacher with sufficient expertise must have a vision of being a ‘case manager’ who not only delivers lessons but also facilitates effective coordination with families and other specialists (e.g., speech therapists, shadow teachers).

As emphasised by Low and colleagues (2020), teacher competence in autism education implies not only possessing the correct knowledge, but also the ability to implement effective teaching strategies and a holistic level of professionalism that embraces inclusive attitudes.

Inclusive Practices for Students with ASD

Inclusive practices for students with ASD do not consist merely of physical placement; they comprise numerous closely interrelated components. These components encompass the arrangement of the physical environment, the adaptation of instructional processes, the support of social participation, and collaboration with families. Odom et al. (2014) emphasise that these practices do not consist of random choices but must be systematic interventions with a strong evidence base.

Classroom Arrangements and Environmental Supports

The sensory and cognitive processing characteristics of students with ASD necessitate a structured physical learning environment. A classroom layout that is clear, predictable, and as free as possible from distracting stimuli supports the student's behavioural regulation. Mesibov and Shea (2010), the developers of the TEACCH approach, state that the structuring of the physical space (for example, separate areas for independent work and group work) and the visual presentation of the daily schedule reduce anxiety and increase independence. Visual supports such as labelled materials, left-to-right work systems, and transition cues help the student find the answer to the question "What do I need to do now?" without the need for constant adult guidance.

Instructional Adaptations and Strategies

Effective instruction for students with ASD requires the adaptation of content presentation and student engagement. Wong et al. (2015) have identified various evidence-based practices required for inclusive classrooms. These strategies include:

1. *Universal Design for Learning:* Minimising barriers for all students by planning instruction from the outset to offer multiple means of presentation (visual/auditory) and multiple means of expression.

2. *Structured Teaching and Task Analysis:* Breaking down complex skills into smaller, teachable steps (task analysis) and using systematic prompts (for example, simultaneous prompting) to ensure errorless learning.

3. *Video Modelling and Social Narratives:* Using video clips or written social narratives to make abstract concepts and social expectations concrete; thereby helping students understand the class's ‘hidden curriculum’.

Supporting Social Participation

Social interaction for students with ASD may not always develop through natural means; therefore, it necessitates intentional structuring. Inclusive classroom practices utilise Peer-Mediated Instruction and Intervention (PMII) as a fundamental tool. As stated by Chan et al. (2009), training peers to model appropriate social behaviours and to initiate interaction significantly increases the social engagement of students with ASD. Furthermore, integrating the student's special interests into play-based activities and systematically creating opportunities for joint attention are of critical importance for fostering a sense of belonging within the classroom.

Family-Teacher Collaboration

Collaboration with the family constitutes a complementary and indispensable dimension of the teacher's inclusive practice skills. Regular communication, joint planning of developmental goals, and sharing strategies that can be sustained in the home environment support the continuous progression of the learning process. Blue-Banning and colleagues (2004) emphasise that collaboration models based on trust, respect and joint decision-making remove the family from a passive position as mere recipients of information and make them active partners in the educational process. This type of collaboration is particularly important in terms of generalising the skills learned at school to everyday life.

Challenges and Barriers in Implementation

Despite inclusive education being legally enshrined and accepted in principle, there remains a significant gap between policy and practice for students with OSB diagnoses. The literature describes these barriers not as isolated incidents but as a multi-layered ecosystem of challenges, ranging from individual teacher competencies to systematic resource allocation. Barry and colleagues (2020), in a comprehensive review, categorise barriers to the implementation of interventions under three headings: practitioner characteristics, organisational capacity, and external factors.

Professional Readiness and Fidelity of Implementation

The primary barrier to successful inclusion often stems from a lack of ASD-specific training. Although teachers possess general pedagogical knowledge, they report frequently feeling unprepared in the face of the complex behavioural and sensory needs of students with ASD. Lindsay et al. (2013) state that this situation leads to burnout in teachers and the development of resistance towards inclusive practices. More importantly, even when teachers attempt to use evidence-based practices, "fidelity of implementation" continues to be a significant issue. Steinbrenner et al. (2020) emphasise that applying strategies without adhering to their original protocols (for example, delivering the prompt at the wrong time) reduces the effectiveness of the intervention. Koçak (2025) attributes this problem to the fact that in-service training generally remains at a theoretical level and to the insufficiency of "in-class coaching" support.

Systemic Constraints and Resource Availability

Implementation barriers show significant variation across different educational contexts. In their study comparing barriers in urban and rural regions, Suhrheinrich et al. (2021) determined that issues of access to specialist personnel and "staff turnover" were dominant in rural regions, whereas overcrowding of class sizes and time constraints were the main barriers in urban regions. Furthermore, although technology is frequently presented as a solution, it brings with it its own set of barriers. Ghanouni et al. (2020) demonstrated that high costs, lack of technical support, and the complexity of devices regarding the use of assistive technologies play a deterrent role for teachers and families.

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Social Acceptance and School Climate

Inclusivity refers not only to academic access but also to social belonging. However, students with OSB are disproportionately vulnerable to bullying and social isolation. Koçak (2025) states that this situation is not only due to the student's lack of social skills, but also due to the school climate's inadequacy in accepting 'difference'. In environments where peers do not have sufficient knowledge about ASD, stereotypical behaviours can become a subject of ridicule; this can increase the student's anxiety levels and negatively affect their participation in the educational process.

Family and Socioeconomic Inequalities

The sustainability of the programme depends on the transferability of interventions to the home environment; however, socio-economic factors may pose a significant obstacle at this point. Koçak (2025) emphasises that low-income families may struggle to actively participate in the process or obtain the necessary materials due to economic constraints and time pressure. Furthermore, the exhaustion that caring for a child with ASD creates for parents should not be overlooked. If the school system does not offer flexible and empathetic support, it becomes nearly impossible for families to consistently maintain home-based interventions.

Professional Development and Recommendations

The dynamic nature of ASD and the constant change in educational strategies require teacher competence to be seen not merely as an achievement but as a lifelong development process. Research shows that the gap between evidence-based practices and classroom practices can only be bridged through planned, goal-oriented, and long-term professional development programmes.

The Necessity of ASD-Specific Training

Broad-scope special education training often remains insufficient in meeting the unique needs of students with ASD. Corkum et al. (2014) emphasise that educators require ASD-specific professional development that directly addresses the core areas of deficit in autism (social communication and sensory processing etc.) rather than general inclusion strategies. When training is too general, teachers experience difficulty in adapting concepts to the complex behavioural profiles in their classrooms. Wei and Yasin (2017) suggest that training programmes should be customised to offer practical and applied strategies that can be directly implemented in general education settings.

The Link Between Professional Development and Self-Efficacy

There is a strong relationship between the quality of professional development and the teacher's belief in their own success (self-efficacy). Johnson et al. (2021) demonstrate that when teachers participate in high-quality professional development programmes, their self-efficacy scores increase significantly, enabling them to persevere more in inclusive practices. Supporting this finding, Kossewska et al. (2021) emphasise that ASD-specific professional development directly increases teachers' confidence in their professional competencies. It is observed that teachers with high perceptions of self-efficacy have a lower probability of experiencing burnout and a higher probability of creating a positive inclusive climate.

Bridging the Gap: Knowledge of Evidence-Based Practices

One of the fundamental aims of professional development is to transfer scientific knowledge into the field of practice. However, studies conducted in the Turkish context indicate a disconnect between this goal and its implementation. İftar and colleagues (2023) report that special education teachers have a positive attitude towards evidence-based practices, but their current level of knowledge and practical experience is generally limited. Similarly, Çil and colleagues (2022) found that teachers need more concrete guidance on how to implement specific interventions, such as video modelling or discrete trial teaching, in crowded classroom environments. In this context, the content of professional development programmes should focus more on "how to implement correctly" rather than "what to teach".

Strategies for Supporting Professional Development

In light of the implementation barriers defined by Barry and colleagues (2020) and the competency frameworks proposed by Koçak (2025), several fundamental strategies for developing teacher competencies emerge:

1. *Transition from Workshops to Coaching:* Traditional, one-day seminars may prove insufficient in bringing about long-term behavioural change. Instead, coaching and mentoring models that include in-class practice increase the retention of skills thanks to experts providing feedback during live lessons.

2. *Focus on Evidence-Based Practices:* Professional development programmes that align with scientifically validated methods (e.g., PMII or early intervention-based approaches) yield more effective results than random or unproven methods.

3. *Interdisciplinary Collaboration Training:* Instead of conducting training separately, joint sessions involving teachers, speech and language therapists, and shadow teachers contribute to the development of a common terminology and a culture of collaboration.

Conclusion and Future Directions

Inclusive education for students with special educational needs refers to a multifaceted paradigm that aims not only for the student to be physically present in the classroom but also to participate actively and meaningfully throughout the process. The competence of the teacher, who is at the centre of this transformation process, cannot be limited to a static checklist of technical skills. This competence is assessed as a dynamic synthesis of in-depth professional knowledge about the spectrum, evidence-based practice skills, and inclusive attitudes that support neurological diversity.

Although current literature and policy documents present inclusive education as a legal foundation, the gap between classroom practices and policy discourse poses a significant problem. Low et al. (2020) and Koçak (2025) emphasise that unless teachers are equipped with specific competencies such as behaviour management, instructional adaptations, and collaboration, there is a high risk that inclusive policies will not be implemented.

Future Directions for Research and Practice

To reduce the gap between research and classroom practice and support sustainable inclusive education for students with ASD, future studies might focus on a few key areas.

1. ***From Workshops to Coaching***: Instead of one-off workshops, professional development could shift to ongoing coaching that looks at teachers' actual classroom activities. Suhrheinrich and colleagues (2021) point out that teachers learn best when they get immediate feedback while teaching.

2. ***Applied Practices:*** Research should not only show which methods work, such as PMII or video modelling, but also how these methods can be used consistently in crowded or low-resource classrooms. Knowing the challenges that make consistent use hard is as important as knowing which methods are effective.

3. ***Technology Use:*** With more digital tools available, teachers need skills in ASD-specific technology. Ghanouni and colleagues (2020) note that handling the cost and ease-of-use of assistive tools is essential to make learning accessible and flexible.

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SECTION 2.
EARLY CHILDHOOD EDUCATION AND DEVELOPMENT

SOCIAL SKILLS AND PROSOCIAL BEHAVIORS IN THE PRESCHOOL PERIOD: A THEORETICAL PERSPECTIVE

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Social Skills

Social skills are defined as a collection of behaviors that enable individuals to communicate with their environment, develop positive attitudes, and express themselves without social disadvantage (Atmaca et al., 2020). Communication is central to this; while it facilitates the acquisition of other talents, difficulties in communication can hinder them (Değirmenci, 2022). Although often confused, "social competence" is a broader concept regarding general social success, whereas "social skills" refer to specific abilities (Merrel & Gimpell, 2014). Childhood is a critical period for this development; while it is possible to learn these skills in adulthood, the process is significantly more challenging (Tutkun & Dinçer, 2019). Social skills assist individuals in coping with difficulties and strengthening interpersonal processes (Baran & Aksoy, 2020; Stanley, 2009). Positive psychosocial health in early childhood is inversely related to future social risks (Jones et al., 2011; Toumbourou, 2011) and is assumed to positively impact future social, behavioral, and educational success (Sanson et al., 2009). Ultimately, these skills represent the capacity to adapt to social environments and manage potential conflicts (Matson & Rivet, 2007).

The importance of social skills

Social skills play a critical role in our lives, allowing individuals to successfully adapt to social environments and take on active roles. Children mature socially by following appropriate behavioral examples in their surroundings and passing through developmental stages. Throughout the socialization process, children learn appropriate behaviors via cues from their environment; this enables them to understand rules, improve communication skills, and express their desires. Environmental factors, such as family structure, cultural values, the educational environment, and the quality of educational programs, are influential in social skill development (Ceylan, 2009; Erbay, 2008; Özbey, 2012).

Since children are involved in social interactions from the moment of birth, they require social skills to make sense of these interactions and develop appropriate responses (Samancı & Uçan, 2017). These skills strengthen communication abilities and facilitate adaptation to the environment. Social skill development begins at birth and progresses gradually over time, depending on the interactions established with the surroundings (AcunKapıkıran et al., 2006). The first six years of life are particularly important, as development continues rapidly and learning capacity is high. Behaviors acquired during this period persist into adulthood and constitute the foundation of the individual's personality structure, habits, and value judgments (Işıkol, 2019; Tuğluk et al., 2008).

Classification of social skills

Social skills develop through interaction with the environment and can vary cognitively and emotionally depending on the setting. Because individuals utilize these skills for specific purposes involving various characteristics, they are often categorized (Atak, 2020). Since social skills describe a wide range of actions and focus on different aspects of social interaction, numerous classifications are encountered in the literature (Gülay & Akman, 2009).

Various researchers have classified social skills differently (Akkök, 2006; Bellack et al., 2004; Caldarella & Merrell, 1997; Gresham & Elliott, 1990; Rinn & Markle, 1979; Zins et al., 2004). Significant classifications include:

- Akkök (2006): Identifies six main categories: relationship building, cooperation, emotional awareness, coping with aggression, coping with stress, and planning/problem-solving.

- Canney and Byrne (2006): Divide skills into four areas: Basic Skills (body language, personal space), interaction skills, emotional skills, and cognitive skills.

- Bellack et al. (2004): Approach the concept through five dimensions: expressive actions, non-verbal actions, social perceptions, interaction behaviors, and situational factors (cultural adaptation).

- Caldarella and Merrell (1997): Based on a review of 21 studies involving children and adolescents, they group skills into five: peer-related skills, self-control, assertiveness, compliance, and academic skills.

- Gresham and Elliott (1990): Classify skills into four groups: cooperation, responsibility, self-control, and assertiveness.

- Rinn and Markle (1979): Examine skills in four groups: self-expression, supporting, asserting rights, and communication skills.

When these groupings are analyzed collectively, it can be said that the foundation of social skills consists of abilities such as expressing thoughts and feelings appropriately, managing the cycle of communication (initiating, maintaining, ending), managing friendships, empathy, following rules, helping others, and seeking help when needed (Köleoğlu, 2023). Despite different definitions, the common focus of these classifications is on fundamental abilities like emotional expression, communication, relationship management, cooperation, and adaptation.

Development of social skills

Development is a continuous process throughout life. According to Yavuzer (2012), this process is dynamic, influenced by genetic characteristics, possesses a sequential and regular structure, and progresses in a balanced manner. Development is a multi-layered phenomenon encompassing physical, cognitive, social, and emotional dimensions. Many social skills are acquired unconsciously and unplanned, first within the family and subsequently through peer interaction (Avcıoğlu, 2007). It can be stated that the roots of social skills are established from the moment of birth, making the first six years a critical period. While the ability to use social referencing increases after the age of two, the awareness that every individual may have different emotional states and reactions begins to develop from the age of three (Santrock, 2016).

In the development of children's social abilities, family characteristics, cultural norms, and early social opportunities play a significant role. Children begin life through interactions with their families, and this secure attachment forms the foundation for relating to others. Establishing a strong communication network with the caregiver contributes to the child developing positive relationships with others and a solid personality structure. Once the school period begins, healthy relationships established with teachers assist in the progression of social skills (Flannagan & Hardee, 1994; Petit et al., 1988; Pianta, 1999). Schools are the places where children experience their first social interactions outside the family, gaining the chance to interact with peers and teachers to develop sharing, cooperation, and language abilities (Emen & Aslan, 2018; Kandır, 2001).

Children learn expectations, rule-questioning, appropriate behaviors, and safety through observations acquired from their families and environment (Broadhead et al., 2010). While learning how to relate to individuals outside the home—especially peers—they develop social skills, learning to share not only toys but also food and adult attention. Like the social development process, learning social skills is gradual (Gülay & Akman, 2009). As children interact more with peers upon starting school, they tend to become less dependent on adults (Oktay, 2007). Merrell (2003) lists necessary preschool social behaviors as: waiting one's turn, following social rules, sharing, working with a group, respecting and defending peer rights, participating in play, using free time effectively, compromising, self-confidence, assertiveness, and apologizing when wrong. Failure to acquire these prosocial behaviors in preschool can lead to numerous problematic behaviors in adulthood (Kaya, 2016).

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The social-emotional outcomes targeted by the MEB (2024) for the preschool period are crucial for supporting development and future relationships. These targets include:

- Address & Communication: Knowing one’s home address and parents' phone numbers for safety.
- Emotional Expression & Empathy: Clearly expressing one's own feelings and understanding/explaining the feelings of others.
- Compliance with Rules: Following societal/home rules and explaining them to others.
- Responsibility & Self-Confidence: Fulfilling simple tasks and communicating comfortably with confidence.
- Communication & Leadership: Interacting with new people, controlling emotional reactions, and taking leadership roles when necessary.

The development of social skills can be fully grasped by examining social development theories. Although these theories (Psychoanalytic, Learning, Cognitive) differ based on the conditions of their times, they agree that play has a critical role in social development. Psychoanalytic theory sees play as a chance to express emotions; learning theory views it as a way to gain new behaviors through reinforcement; and cognitive theory suggests it aids social skill development through role-playing (Gülay & Akman, 2009). Ultimately, early social skills contribute to children establishing healthy relationships, increasing academic success, and becoming adaptable individuals in the future.

Theoretical approaches

In this section, we will examine in detail the theoretical frameworks we will use to understand the development of prosocial behaviors in preschool-aged children. Fundamental theories such as psychoanalytic theory, psychosocial theory, social learning theory, attachment theory, ecological systems theory, cognitive approach theory, and behavioral approach theory will be examined in the context of their roles in the development of children's social skills and prosocial behaviors.

Psychoanalytic theory

Sigmund Freud, the founder of psychoanalytic theory, posits that humans are instinctively selfish beings driven by irrational sexual and aggressive impulses (Ateş & Sağar, 2024). To manage these hostile drives in relation to their parents, children develop a "superego" between the ages of four and six. This structure arises from the child identifying with the same-sex parent and internalizing their values. Consequently, prosocial behaviors often emerge as defense mechanisms employed by the ego to satisfy the superego's demands and avoid guilt (Eisenberg et al., 2006).

Other theorists offer varying perspectives on social behavior within this framework. Carl Gustav Jung emphasizes that maturity is achieved by moving away from individualism and developing feelings of solidarity and altruism (Jacobi, 2002). Conversely, Alfred Adler (2003) links empathy and helping behaviors to a sense of superiority, suggesting that individuals may help others primarily to satisfy their own need for superiority. Finally, Fromm (1991) notes that while humans possess aggressive and destructive impulses alongside good ones, true humanity is sustained only through respect, love, responsibility, and care.

Psychosocial theory

According to Erikson's psychosocial development theory, development is a continuous process spanning from birth to death, divided into eight stages. Within this framework, social skills and prosocial behaviors are evaluated across a broad developmental timeline. The preschool period specifically covers three critical stages:

1. **Basic Trust vs. Mistrust (0–1.5 years):** Psychosocial development begins in infancy. As infants are dependent on care, establishing a bond of trust with caregivers is essential. This forms the foundation of communication and future relationships (Tokuşlu, 2022).

2. **Autonomy vs. Shame and Doubt (1.5–3 years):** In this transition to early childhood, the focus shifts to exploring the environment and learning social skills through non-verbal cues. Parental approval during this stage fosters self-acceptance and higher-quality communication skills (Berk, 2018).

3. **Initiative vs. Guilt (3–6 years):** Defined as early childhood, this stage involves increased interaction with others, often through preschool education. Children develop social skills such as leadership, self-expression, and initiative through play and peer interaction (Berk, 2018).

Successfully navigating the specific conflicts of these stages is crucial for developing a healthy personality structure. For instance, the trust established in infancy and the will developed in toddlerhood lay the groundwork for prosocial behaviors like helping, sharing, and empathy.

Social learning theory

Social Cognitive Theory posits that children learn behaviors by imitating individuals in their environment (Koç, 2009). According to Bandura, moral rules are shaped by information derived from intuition, social reactions, and role models; individuals determine appropriate behaviors based on these experiences (Bandura, 2002; Hoffman, 2000). Prosocial development is driven by personal and self-regulatory processes (Bandura, 2002), with self-efficacy and empathy playing significant roles in promoting these actions (Bandura et al., 2003). Consequently, the ability to regulate emotional states is a critical factor in the execution of prosocial behaviors (Eisenberg et al., 2006). Ultimately, this theory provides a fundamental framework for understanding how individuals acquire new social behaviors, gender roles, and moral standards through observation and modeling.

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Attachment theory

Attachment is defined as a relationship type developed between infants and caregivers that provides emotional comfort and a sense of security (Öztürk & Tortop, 2019). John Bowlby's Attachment Theory distinguishes itself from other social development theories by viewing attachment not as a symptom of pathological dependency, but as a natural, routine process that protects children from environmental threats during critical developmental stages (Keleş & Küçükturan 2019; Reisz et al., 2018). Bowlby emphasized the biological readiness of both mother and infant for this process and the vital importance of sensitive care during the first year (Santrock, 2016).

Bowlby classified the attachment process into four distinct stages (Schaffer, 1996):

- Pre-attachment (0–2 months): Infants display attachment behaviors indiscriminately toward all humans.

- Attachment-in-the-making (2–7 months): Infants begin to distinguish familiar figures from strangers, developing a stronger bond with the primary caregiver.

- Clear-cut attachment (7 months – 2 years): Specific attachment relations are fully formed, facilitated by developments in language and interaction.

- Reciprocal relationship (2+ years): Children become aware of others' emotions and use this information to shape their behavior.

According to attachment theorists, the social-emotional behaviors exhibited throughout a person's life are shaped by these early relationships (Santrock, 2016). Infants whose needs are met sensitively develop a sense of security, whereas those who are neglected may develop aggressive attitudes, and those receiving inconsistent care may display ambivalent behaviors. These early interactions form the mental schemas that shape future relationships (Wong et al., 2009). Consequently, a secure attachment style is crucial for supporting prosocial behaviors such as empathy, altruism, and sharing in the preschool period.

Ecological systems theory

Developed by Urie Bronfenbrenner in 1979 and later termed the 'bioecological theory,' this framework defines the ecological aspects of human development. Bronfenbrenner describes this process as life-long interactions occurring within the contexts of the individual's environment (Tudge, 2019). This perspective necessitates a holistic evaluation of the environment (Bronfenbrenner, 1979) and emphasizes the complex interactions between environmental and socio-cultural factors (Twintoh et al., 2021). To understand development, it is essential to evaluate the child not in isolation, but in conjunction with their environment.

The theory organizes the social environment into nested structures comprising four subsystems (Lindo, 1997; Obalar & Ada, 2013):

- Microsystem: Involves the individual's direct relationships and immediate environment.
- Mesosystem: Encompasses interactions between the different environments in which the individual actively participates (connections between microsystems).
- Exosystem: Refers to environments where experiences occur that affect the individual, even though the individual is not active there.
- Macrosystem: Represents the broader beliefs, cultures, and lifestyles (Demirkasımoğlu & Eranıl, 2021).

Ecological Systems Theory explains development through environmental interactions rather than solely through individual traits. It is particularly significant for understanding prosocial behaviors, as these behaviors stem from the child's interactions with these various ecosystem layers.

Cognitive approach theory

According to Kohlberg, moral development is a component of social cognitive development that proceeds through fixed, universal, and hierarchical stages. As children enhance their cognitive and perceptual skills, they acquire the ability to interpret emotional cues and view the world from others' perspectives (Shapiro, 2013). Similarly, Piaget developed his theory by observing children's play and engaging them in dialogues about rules, justice, and equality (Wright & Croxen, 1989). He posited that moral development relies on mutually supportive concepts like autonomy and reciprocity, as morality cannot exist without social relations (Çam et al., 2012).

While Piaget and Kohlberg argued that limited perspective-taking abilities in young children delayed the emergence of prosocial actions until elementary school, Eisenberg emphasized that socio-cognitive development and environmental emotional factors are crucial for prosocial behavior (Eisenberg et al., 2006). The cognitive approach asserts that internal mental processes—thoughts and beliefs—shape social interactions. By enabling children to understand emotions and take perspectives, these cognitive processes are essential for exhibiting appropriate social behaviors.

Behaviorist approach theory

This theory posits that children's behaviors are fundamentally shaped through reward and punishment. While rewards contribute to the strengthening and continuation of desired social skills, punishment aims to reduce unwanted behaviors. Driven by the desire for social acceptance, socially approved behaviors are reinforced; thus, social skill development is achieved through systematic reinforcement (Berk, 2018).

Founded by John B. Watson, Behaviorism emphasizes the role of environmental stimuli in determining behavior, opposing the focus on conscious experience. Watson argued that development consists of well-learned connections

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between external stimuli and observable responses. Since it suggests children have no innate tendencies but develop through environmental interaction, Behaviorism serves as an essential framework for understanding the acquisition of prosocial behavior.

Prosocial Behaviors

Social development comprises two fundamental components: prosocial and antisocial behaviors (Yağmurlu & Candan-Kodalak, 2009). While early studies focused on antisocial behaviors like aggression, research since the 1970s has increasingly shifted toward prosocial behaviors (Eisenberg et al., 2006). This shift is driven by findings that early prosocial behaviors significantly impact interaction quality, academic success, and psychological satisfaction (Kumru et al., 2004; Paulus & Moore, 2012; Taygur-Altıntaş & Yıldız-Bıçakçı, 2017).

Prosocial behaviors are voluntary actions intended to benefit others without coercion (Mussen & Eisenberg, 1989), serving as a "social glue" that maintains peace within communities (Lay & Hoppmann, 2015). Defined variously as sharing, helping, and protecting (Sarmadi & Flouri, 2016), these behaviors are synonymous with "positive social behavior" and stand as the antithesis to antisocial actions (Akbaba, 1994; Önal, 2018; Uzmen, 2001).

The concept is closely linked to **altruism**—a high-level moral construct involving voluntary, beneficial actions motivated by moral beliefs rather than expectation of reward (Bar-Tal & Raviv, 1982). However, prosocial behavior is the broader term, with altruism forming a specific subset (Scott & Seglow, 2007). Carlo and Randall (2002) classify prosocial behaviors into sub-dimensions: altruistic, compliant, emotional, public, anonymous, and emergency.

Prosocial actions encompass helping, sharing, cooperating, and donating (Bartal & Raviv, 1982). They can be categorized into two main types:

1. **Egoistic:** Motivated by relieving one's own distress or avoiding criticism.

2. **Altruistic:** Motivated by positive values and concern for others, without self-interest (Çalık et al., 2009).

Definitions of prosocial development include both motivational and behavioral elements. While motivational approaches focus on the intent (selfless help), behavioral approaches focus on the action itself—providing benefit or support—regardless of intent, as determining true motivation is difficult (Shaffer, 1979). Motivations can range from obligation and fear of criticism to genuine altruism (Bartal, 1982; Hasting et al., 2007).

Types of prosocial behavior

This section will address the fundamental prosocial behavior types expected to be developed by children in the preschool period. Topics such as empathy, cooperation, sharing, helping, and responsibility will be examined in detail in the context of how these behaviors contribute to children's social skills.

Empathy

According to Hoffman (1987), empathy is the emotional response an individual shows that is appropriate to the situation of the person they are communicating with, rather than their own situation. Carl Rogers, on the other hand, defines empathy as an individual's ability to put themselves in someone else's shoes, understand that person's feelings and thoughts, and view situations from their perspective (Dökmen, 2023). Another definition states that it is an emotional process focused on the sharing of emotional behavior (Feshbach, 1975). Empathy is also defined as the sharing of feelings between the individual and the person opposite them (Roberts and Strayer, 1996) and as the emotional responses that a person will give in accordance with the emotional state and situation of other people (Eisenberg and Strayer, 1987).

According to Kohut (1959), empathy has an important place among the techniques used to understand an individual's inner world. Empathy is understanding the feelings of others in any given situation and the resulting behavior, which is similar to what the other person feels (Damon et al., 2006).

In his study, Kalliopuska (1992) found a positive relationship between individuals' empathy skill levels and their self-esteem and psychological development levels. Some researchers have stated that empathy is an innate skill and that this skill needs to be developed and strengthened (Martin and Clark, 1982; Sagi and Hoffman, 1976; Simner, 1971).

Wispe (1987) states that empathy skills have become increasingly important in studies related to children's social-emotional development over time. Most studies emphasize that children with high levels of empathy tend to have higher social-emotional adjustment and self-esteem in adulthood, are more inclined to exhibit prosocial behaviors such as sharing, cooperation, and helping, display less aggressive behavior, and are more accepted by their peers (Eisenberg and Fabes, 1998; Feshbach and Feshbach, 1982; Grossman et al., 1997; Kalliopuska and Ruokonen, 1993; Roberts and Strayer, 1996). Rogers (1975), on the other hand, stated that empathy is not an innate trait but can be learned, and that appropriate environmental settings can greatly enhance the development of empathy. He noted that families, therapists, and teachers, among others, can contribute to this development. The common ground shared by these researchers with different views and opinions is that empathy skills can be developed and that actions taken in this direction are very important and necessary.

Eisenberg and Mussen (1989) argue that empathy is the most important skill among prosocial skills. Hoffman (2008) states that empathic skills lead to prosocial behaviors such as helping others. It has been stated that empathic concern is an important and critical factor that mediates prosocial behaviors (Eisenberg and Mussen, 1989). According to this perspective, empathy is the foundation of prosocial behaviors and an important factor in exhibiting these behaviors. Beaty (1998) emphasized that children who lack empathy skills do not behave naturally in prosocial behaviors such as helping, sharing, and cooperating (Beaty, 1998).

In a study, Weston and Main (1980) found that when 1-year-old infants saw a sad person, their parents reported in questionnaires that the infants attempted to comfort the person by engaging in behaviors such as hugging, kissing, or touching. In another study along these lines, it was observed that children who reacted emotionally to situations where other individuals were distressed often exhibited various behaviors to comfort that individual (Radke-Yarrow et al., 1983; Radke-Yarrow and Zahn-Waxler, 1984). Based on these research findings, it can be said that facial expressions, which are a concrete indicator of emotional empathy, provide clues as to whether children will exhibit prosocial behavior. If children have high levels of empathy skills, they are more likely to exhibit prosocial behavior.

Contrary to researchers who state that preschool children's thoughts and feelings are egocentric and therefore their empathy skills cannot develop, conducting studies that influence the development of empathy skills during this period may contribute positively to affective empathy, even if it does not affect cognitive empathy, which some researchers define as “true empathy” (Özer, 2016). Therefore, rather than ignoring the newly developing empathy skills in children during this period, it is important to provide them with education that is thought to contribute to this skill, even if only slightly. This effect, which may seem small during childhood, will have a significant impact in adulthood.

Cooperation

Cooperation is defined as the combination of energies by individuals who share the same goals and interests (Sözkesen, 2015). It contributes to the effective and rapid completion of tasks while offering opportunities to establish friendships. In this respect, cooperation is characterized as a prosocial behavior where mutual interests are considered (Tomasello & Warneken, 2009). Research indicates that cooperation skills in the early years positively contribute to the development of peer interactions (Uzmen, 2001).

The development of cooperation skills begins when the child starts using the pronoun "we" (Oğuzkan & Güler, 1996) and is initially exhibited through play (Gülay & Akman, 2009). By the age of five, children reach a specific social maturity, making their cooperation with peers more distinct and conscious (Aslan, 2008).

Ashman and Gillies (1998) investigated the relationship between academic skills and cooperative actions in children aged 6-8. Their study compared a group receiving structured education on cooperative behaviors against a control group. The results demonstrated that children receiving the structured training showed higher levels of cognitive and language development, made greater progress in reading skills, and achieved higher scores on academic tests.

Helping behavior

Helping behavior, which ranks high among prosocial behaviors, is defined as acting to relieve the distress of others in times of need without the expectation of reward (Ayten, 2009; Fersahoğlu, 2001). It encompasses cooperation, solidarity, and empathy (Göçmen, 2019), as well as the sharing of material and spiritual resources (Ekinci, 2018). This virtuous behavior is rooted in the belief that values increase when shared (Çelik, 2014) and serves as a foundation for societal peace and collective happiness (Yılmaz, 2023).

As a social necessity, helping should be taught from the earliest years. While children may cognitively understand the concept, true acquisition occurs through practice—such as sharing toys or participating in charity—rather than mere theoretical knowledge (Aydın, 2003). Acquiring this behavior during the preschool period is critical (Bektaş & Karadağ, 2013; Bierhoff, 2002). Children begin by mimicking observed behaviors; even at 18 months, they exhibit altruistic helping, which increases in frequency over time (Warneken & Tomasello, 2009). According to Yavuzer (1992), after age 6-7, socialization increases through group play, and egocentrism diminishes, leading to a greater tendency for cooperation and helping.

Research supports that helping is an innate, voluntary tendency in early childhood, observed even in infants as young as 14 to 18 months (Warneken & Tomasello, 2009). While 3 and 4-year-olds demonstrate helping behaviors (Collier-Baker et al., 2014), studies indicate that 6-year-olds exhibit these behaviors more frequently than younger children (Bar-Tal & Raviv, 1982), suggesting a developmental progression.

Responsibility

Responsibility is a trait acquired through education, defined as the fulfillment of tasks appropriate to a child's developmental level starting from early childhood (Erman & Arcagök, 2024). It has been defined through various perspectives:

- Cüceloğlu (1999) defines it as "being ready to be held accountable," emphasizing that accountability requires both the necessary skills/knowledge and freedom of action. He argues that personality integrity is impossible without this skill.
- Yavuzer (1997) describes it as the child performing their own tasks according to their age and gender.
- *Şahan (2011)* views it as a synthesis of thoughts, emotions, and skills resulting from making mature choices in daily life.
- Başaran (1974) focuses on the capacity to account for the results of an undertaken duty.

Responsibility is not hereditary; it must be learned (Tuzcuoğlu, 2003). The family is the primary environment for instilling this consciousness, alongside values like respect and trust. Values instilled in early years act as keys to a happy and successful life (Civelek, 2006). Children who acquire responsibility grow into individuals who possess social consciousness and respect for ethical values and their environment (Çelebi-Öncü, 2002). Furthermore, social-emotional development is a determinant of future identity; to achieve social harmony, individuals must possess skills such as rule compliance, relationship building, and emotional control (Özyürek & Ceylan, 2014).

Factors affecting prosocial behavior

This section will address the genetic and environmental factors that influence prosocial behavior. Genetic factors such as age, gender, and temperament will be examined, while environmental factors including family, number of siblings and birth order, culture, preschool education, and peer relationships will be explored in detail.

Genetic factors

Age

As children grow, observable changes in social behavior emerge, driven by maturation and life experiences. Generally, the frequency, variety, and patterns of prosocial actions increase with age (Eisenberg et al., 2006). Research indicates a continuity in positive social actions over time. For instance, a longitudinal study recording the reactions of 1-2-year-old infants to their mothers' distress found that five years later, two-thirds of these children maintained consistent patterns of reacting to the distress of others (Radke-Yarrow & Zahn-Waxler, 1984). The most distinct increase in prosocial actions is typically observed during early childhood, particularly upon starting kindergarten. However, while these behaviors increase with age during the preschool period, the rate of increase slows significantly in adulthood (Eisenberg et al., 2006).

Gender

Gender-based differences in social behaviors begin to appear around 18 months and become more distinct by the end of the preschool years (Geary, 2003). Generally, girls are observed to be more social and use social skills more effectively than boys (Chiu, 2001). Eisenberg and Mussen (1989) highlight that girls exhibit more prosocial behavior and altruism, attributing this largely to child-rearing techniques derived from gender roles. Girls are also more inclined to provide high levels of emotional support, engage in intimate sharing, and offer guidance in problem-solving (Geary, 2003).

Research supports the impact of gender on these behaviors; girls are consistently found to be more empathetic, sympathetic, and involved (Randall & Carlo, 2002). According to Altay and Güre (2012), girls display prosocial actions—such as cooperating, sharing, and comforting distressed peers—more frequently than boys. This divergence is reinforced by societal expectations: society generally expects girls to be helpful and comforting, while demanding independence and task-orientation from boys (Eisenberg et al., 2006). Culturally, girls are often rewarded for caregiving behaviors (Eisenberg & Mussen, 1989), a tendency reflected in play activities where girls frequently enact prosocial roles, such as caring for a baby while playing house (Çelik-Kahraman, 2019).

Temperament

Temperament is defined as stable, genetically based individual differences that emerge early in life (Berk, 2018; Aytar-Güngör, 2016). These hereditary tendencies determine how individuals react to their environment, thereby shaping their perceptions and relationships (Bağcı, 2015). Temperament plays a pivotal role in social development by influencing self-regulation—the ability to control emotions and behaviors—where empathy serves as a crucial factor in generating appropriate responses (Yağmurlu & Candan-Kodalak, 2009).

While children can be classified using various descriptors (e.g., energetic, shy, extroverted), Sanson et al. (2000) identify four fundamental types: reactivity, persistence, warmth, and rhythmicity. In the context of prosocial behavior, children characterized as "warm" and "persistent" are expected to exhibit higher levels of helping, caring, and sharing compared to their "shy" or "reactive" peers (Çelik-Kahraman, 2019).

Environmental factors

Family

As the fundamental unit of society, the family plays a critical role in guiding children toward prosocial behaviors from the very beginning (Tezel-Şahin & Özyürek, 2016). Parents serve as influential models; their supportive attitudes and coping strategies encourage the formation of similar behaviors in children (Orte et al., 2015; Özcan, 2016). Families shape these skills through methods such as direct instruction, modeling, reinforcement, and fostering empathy (Carlo et al., 1999; Serttaş, 2019). Additionally, the presence of siblings positively contributes to social adaptation and behaviors like cooperation and sharing (Toy, 2006; Türkmen, 2018).

Ultimately, social development is molded by the quality of parental education, secure attachment, and sibling relationships (Reichle & Gloger-Tippelt, 2007; Schmidt-Denter et al., 1994; Yavuzer, 2012). Children who feel loved and supported experience less anxiety regarding the outside world and demonstrate increased sensitivity to the needs of others (Zahn-Waxler et al., 1979).

Number of siblings and birth order

Sibling relationships play a pivotal role in the development of social-emotional skills, acting as either positive or negative role models (Taygur-Altıntaş & Yıldız-Bıçakçı, 2017). This interaction is often bidirectional; for instance, when older siblings care for younger ones, it enhances emotion regulation and cognitive skills for both parties (Bağcı, 2015). However, the impact depends heavily on the quality of the relationship. While positive relations foster emotion regulation and prosocial behaviors, negative relations can lead to adjustment problems, anxiety, and aggression (Küçükturan & Keleş, 2020).

Research indicates that older siblings tend to exhibit prosocial behaviors more frequently, and an increased number of siblings correlates with a higher tendency for helping and altruism (Eisenberg et al., 2006). The presence of siblings provides natural opportunities to practice skills like comforting, cooperating, and sharing (Santrock, 2016). For example, Öztürker (2014) observed that among six-year-olds, girls with working mothers and multiple siblings displayed the most prosocial behaviors. Additionally, birth order influences social-emotional development due to variations in parental attention, time, and resources experienced by each child (Keleş & Küçükturan, 2020).

Culture

Culture is defined as the aggregate of values, beliefs, traditions, and social norms of a society. Individuals grow and develop under this nurturing influence (Günindi, 2008), learning and adopting culturally appropriate prosocial behaviors first within the family and subsequently in environments such as schools and peer groups (Kumru et al., 2004). Cultural differences and similarities interact with and influence children's emotional responses and prosocial behaviors (Trommsdorff et al., 2007). Consequently, actions like helping and cooperating are deeply intertwined with a society's character and traditions (Özdemir, 2010; Serttaş, 2019).

The value placed on prosocial behaviors varies across cultures, affecting socialization. For instance, in West African societies, behaviors ensuring social unity are encouraged from childhood (Eisenberg et al., 2006). Similarly, Kibbutz communities minimize competition and foster cooperation, contributing to high levels of social responsibility and generosity in children (Eisenberg & Mussen, 1989).

Research supports that children in traditional rural societies often exhibit more cooperative behaviors than those in urban or Western cultures (Eisenberg & Mussen, 1989). Even within the same society, variations exist; Whiting and Whiting (1975) found that within the American context, children from non-Western communities living in large families with working parents demonstrated higher performance in helping and cooperation compared to children from typical American families.

Early childhood education

Preschool institutions serve as critical environments outside the home where children socialize, reveal natural talents, and meet developmental needs through various programs (Bağcı, 2015). According to the Ministry of National Education (MEB, 2024), the goal of these institutions is to support holistic development and foster positive habits. Through peer interactions in this setting, children learn to recognize emotions, respect rights, and acquire prosocial behaviors—such as comforting others—more easily.

Interactions with adults and peers enable children to understand others' perspectives, thereby enhancing their prosocial skills (Önal, 2018). Teachers play a pivotal role by acting as role models of empathy and kindness, providing clear instructions on helping and sharing, and reinforcing these behaviors (Mussen & Eisenberg, 1989). Research confirms that preschool education increases sociality, and the skills acquired during this critical period—such as sharing toys and cooperation—tend to persist into elementary school (Eisenberg et al., 2006; Hyson & Taylor, 2011; Sebanc, 2003; Trawick Smith, 2014).

A warm, open, and secure teacher-child relationship directly influences positive social development (Önal, 2018). Significant correlations exist between the quality of this relationship and the child's prosocial behavior; while close relationships increase prosocial actions, controlling attitudes do not yield the same effect (Hastings et al., 2007; Howes, 2000; Kienbaum, 2001). Experimental studies further indicate that teachers' prosocial behaviors reduce aggression and increase helping behaviors in children aged 5-7 (Flannery et al., 2003). Additionally, educational interventions, such as using picture books focused on helping and sharing, have been shown to increase the frequency of these behaviors (Uzmen & Mağden, 2002).

Peer relationships

Peer relationships in preschool are fundamental for social skill acquisition. Children who fail to cooperate or help others risk exclusion (Eisenberg et al., 2006), whereas healthy peer bonds facilitate the learning of social norms and prosocial behaviors (Sebanc, 2003; Önal, 2018). These interactions play a significant role in developing physical, mental, and social capabilities (Aral et al., 2000; Santrock, 2016).

Advances in language and perspective-taking enable children to exhibit empathy and comforting behaviors, such as a six-year-old reassuring a younger child (Berk, 2018). Eisenberg and Mussen (1989) note that while 30% of prosocial behaviors occur spontaneously, this rate increases to 48% during active peer interaction involving requests or feedback.

Play serves as a critical medium where children negotiate roles, resolve conflicts, and model behaviors like helping and sharing (Santrock, 2016; Çelik-Kahraman, 2019). Friendship offers a unique "equal platform" for learning; Berk (2018) highlights that prosocial skills are prerequisites for successful friendships, noting that friendly children establish satisfying relationships more easily than their aggressive or withdrawn counterparts (Trawick Smith, 2014).

Related Studies

The development of social skills and prosocial behaviors during the preschool period is of paramount importance for establishing healthy social relationships in later life. Consequently, research examining the effects of educational programs designed to support children's social and emotional development has increased in recent years. The literature contains numerous studies addressing the relationship between social skills training, family involvement, and prosocial behaviors. These studies demonstrate that behaviors such as empathy, sharing, helping, and cooperation can be enhanced through various educational interventions. Furthermore, it is emphasized that the active role of families in this process strengthens children's social learning experiences. This section presents national and international research examining the effects of social skills and family education programs implemented in the preschool period on children's prosocial behaviors.

Bolat (2023) investigated the relationship between the prosocial behaviors of 286 Turkish preschool children (aged 60-72 months) living in Germany and their fathers' prosocial behaviors and perceptions of the paternal role. Data were collected using a "Demographic Information Form," the "Child Prosociality Scale," the "Adult Prosociality Scale," and the "Fatherhood Role Perception Scale." The study revealed a significant positive relationship between children's prosocial behaviors and their fathers' prosocial behaviors. A weak but significant positive relationship was also found between Adult Prosociality and Paternal Role Perception, with adult prosociality being a significant predictor of the level of paternal role perception. Additionally, it was observed that fathers' prosociality levels decreased as their duration of residence in Germany increased.

Ata (2022) investigated the effect of a "Prosocial Support Education Program," developed for the parents of 37 primary school children, on the prosociality levels of both children and parents. Instruments included the "Child Prosociality Scale (Child Form)," the "Child Prosociality Scale (Parent-Teacher Form)," and the "Adult Prosociality Scale." The study concluded that the applied education program had a positive effect with a medium effect size on the parents and children in the experimental group.

Günindi (2022) researched whether there was a difference in social adaptation skills caused by different educational environments among 159 five-year-old children continuing face-to-face education and 137 children continuing online education due to the pandemic. Using the "Social Adaptation Skills Scale (SASS)," the study found a significant difference in the social adaptation sub-factor in favor of the face-to-face education group, while social maladjustment sub-factor scores were significantly lower in this group compared to the online group.

Bozkurt (2022) examined the effect of a developed prosociality education program on the prosocial behaviors of 52 children aged 60 to 72 months. Data were collected using a "Personal Information Form" and the "Child Prosociality Scale (CPS) - Mother, Father, and Teacher Forms." The study observed that the Prosociality Education Program positively affected children's prosocial behavior scores, according to teacher opinions.

Kanyılmaz-Canlı (2022) investigated the effect of a "Forest School-Based Prosocial Support Program" on the prosocial behaviors of 42 children in the 4-6 age group. The study utilized a "Child-Family Demographic Information Form," "Child Prosociality Scale," "Preschool Social Value Acquisition Scale," and a "Prosocial Behavior Interview Form" developed for the research, along with video recordings. The findings indicated that the Forest School-Based Prosocial Support Program was an effective intervention for developing children's prosocial behaviors.

Bağcı-Çetin (2021) explored the effect of a "Prosocial Behavior Psychoeducation Program" applied to 30 children in the 5-6 age group on their prosocial behaviors, social-emotional adjustment, and life satisfaction. Measures included the "Prosocial Behavior Scale," "Social Competence and Behavior Evaluation Scale-30 (SCBE-30)," and the "Life Satisfaction Scale (Child Form)." The study found a significant positive difference between the pre-test and post-test mean scores of the experimental group regarding prosocial behaviors, the social competence sub-dimension of social-emotional adjustment, and life satisfaction.

Genç (2021) investigated the effect of mothers' prosocial behaviors and attitudes on the prosocial behaviors of 204 children. Data were collected using a "Demographic Information Form," "Child Prosociality Scale (For Mother and Teacher)," "Adult Prosociality Scale," and the "Parental Child-Rearing Attitudes Scale (PCRAS)-Mother Form." The study concluded that there is a significant positive relationship between mothers' prosocial behaviors and their children's prosocial behaviors. Furthermore, it was determined that the children of mothers exhibiting democratic attitudes displayed better prosocial behaviors.

Karaman and Dinçer (2020) examined the effects of variables such as number of siblings, age, years of preschool attendance, gender, and parental education level on the prosocial behaviors of 290 children aged 25 to 72 months. Using the "Parental Attitude Scale (PAS)," "Child Prosociality Scale (CPS)," and a "Demographic Information Form," the study found that girls scored higher than boys, older children scored higher than younger ones, and those who attended kindergarten for more than half a year scored higher than new starters.

Berti and Cigala (2020) researched the effect of a mindfulness-based program on the social-emotional skills of 21 preschool children aged 3-6. Data collection tools included the "Coding Grid," "Head-Toes-Knees-Shoulders Task," "Do-Don't Task," "Emotion Understanding Test," "Two False Belief Tasks," "Appearance-Reality Distinction Task," "Two Visual Perception Tasks," and a "Hiding Game." The study showed that the applied program positively affected prosocial behaviors, processes inhibiting self-regulation, and perspective-taking skills within emotional and cognitive components.

Çelik-Kahraman (2019) aimed to develop a prosocial behavior scale and investigate the effect of certain variables on prosocial behavior in a study involving 499 children aged 48-72 months. The scale was developed to evaluate prosocial behaviors based on responses to illustrated problem situations. Results indicated that prosocial behavior scores were higher among children in the older age group, those with higher birth orders, and those with parents having high education levels. The developed scale demonstrated high validity and reliability.

Çubukçu (2019) examined the relationship between the prosocial behaviors of 198 preschool children aged 48-72 months and their mothers' prosocial behaviors and parenting attitudes. Instruments included a "Personal Information Form," "Child Prosociality Scale-Mother and Teacher Form," "Adult Prosociality Scale," and "Parental Attitude Scale." The study found that children aged 60-72 months had higher scores, and a significant positive relationship existed between mothers' prosocial behavior scores, authoritative attitudes, and the child's prosocial behavior score.

Dereli (2019) investigated the relationship between aggression types, moral-social rule knowledge, and positive social behaviors in 310 children aged 4-5. Using the "Preschool Social Behavior Scale-Teacher Form" and the "Moral and Social Rule Knowledge Perception Scale," the study observed that prosocial behavior scores and aggression type scores significantly affected moral and social rule knowledge perception scores.

Goncharova and Ross (2019) researched the relationship between self-awareness and prosocial behavior with 98 parents of children aged 11-54 months. Using the "Early Prosocial Behavior Questionnaire," "Stipek Self-Concept Questionnaire," and "Parent Report of Children's Abilities," the study found a significant positive correlation between age/cognitive development and self-awareness/prosocial behaviors.

Longobardi et al. (2019) investigated the effect of empathic concern, receptive language, theory of mind, and perspective-taking skills on the prosocial behaviors of primary school children aged 8-11. Using the "PPVT-R," "gaze-prediction and word-prediction tasks," "How I Feel in Different Situations Questionnaire," and "Social Adaptation Ability Indices Questionnaire," the study determined that empathic concern, receptive language, theory of mind, and perspective-taking skills all positively affected prosocial behaviors.

Conte et al. (2018) examined the influence of emotion knowledge, theory of mind, and language skills on the formation of prosocial behaviors in 149 Italian children aged 24-47 months. Using a mixed method of natural observation and direct tasks, the study found a significant relationship between children's social cognition scores and the exhibition of prosocial behaviors.

Coyne et al. (2017) investigated the relationships between interactions with superheroes and prosocial, defending, and aggressive behaviors in 240 preschool children. Parents reported on children's media use and outcomes at two different times. The study concluded that preschool children's interactions with superheroes were associated with an increase in aggressive behaviors the following year, but not with defending or prosocial behaviors.

Howes et al. (2008) researched the effect of a program applied to 2,439 four-year-old children receiving preschool education on their language skills, academic status, and social skill development. The preschool program was examined in terms of infrastructure, adherence to nine quality standards regarding design, classroom environment, and student-teacher interaction. The study determined that practices strengthening teacher-student relationships, program development, and professional development efforts could facilitate children's school readiness. Furthermore, students in preschool institutions maintaining these practices were observed to have better academic, language, and social skill levels.

In conclusion, research in the literature demonstrates that social skills and family education programs implemented in the preschool period play a significant role in the development of children's prosocial behaviors. Findings indicate that such programs strengthen children's skills in empathy, sharing, helping, and cooperation. Additionally, it has been determined that family participation increases the effectiveness of education, enabling children to transfer acquired skills to their daily lives more easily. Overall, studies integrating social skills training with family education appear to provide a stronger contribution to children's social-emotional development. In this context, paralleling the findings in the literature, the present research aims to examine the effect of the combined implementation of social skills and family education programs on supporting the prosocial behaviors of preschool children.

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THE STEM EDUCATION IN EARLY CHILDHOOD

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INTRODUCTION

The conceptualization of STEM education itself underscores this integrative perspective. Rather than treating science, technology, engineering, and mathematics as isolated domains, STEM refers to an interconnected learning approach in which multiple disciplines are mobilized to address real-world problems. In early childhood settings, STEM is defined as a learning environment where one or more disciplines are used in a connected way with active participation of children (Yelland & Waghorn, 2023). This definition aligns with developmental research highlighting the preschool period (3–6 years) as a crucial window for fostering cognitive, linguistic, social, and physical growth. During these years, children naturally explore, ask questions, manipulate materials, and learn through play; thus, STEM-oriented pedagogies strategically leverage these tendencies to cultivate curiosity, inquiry, and early problem identification and solving skills (Martinez et al., 2024).

Integrated STEM education plays a critical role in supporting learners' creativity, problem-solving, and ability to apply knowledge across real-life contexts. Research shows that linking science, technology, engineering, and mathematics into a unified instructional approach strengthens students' exploration and meaningful learning (Güngör & Köse, 2022; Demir & Köse, 2022). Moreover, STEM education emphasizes essential 21st-century skills such as critical thinking, innovation, and lifelong learning while positioning technology as a cognitive tool that enables learners to construct and interpret knowledge effectively (Kurtuluş, 2023; Güngör & Köse, 2023; Köse, Kurtuluş & Bilen, 2020). Taken together, these findings highlight STEM's importance in fostering holistic development and preparing individuals for complex future challenges. An expanding corpus of international and national research reinforces the importance of introducing STEM in the preschool years (Tippett & Milford, 2017; Wan, 2021). Longitudinal evidence suggests that children exposed to STEM-rich environments develop stronger foundations in science and mathematics in later schooling (Farris & Purper, 2021). Importantly, contemporary discussions emphasize that early childhood STEM education does not aim to teach abstract scientific concepts prematurely; rather, it seeks to nurture habits of mind such as experimental thinking, wonder, and a desire to understand natural and technological phenomena (Zviel-Girshin & Rosenberg, 2025). Young children who participate in hands-on and exploratory STEM activities tend to show higher confidence, deeper engagement, and greater persistence in problem-solving. Recent evidence indicates that inclusive, play-based STEM experiences encourage children to take intellectual risks, try alternative strategies, and collaborate effectively with peers. Monteira and Di Santo (2025) found that such environments strengthen children's self-efficacy and flexible thinking, suggesting that developmentally appropriate STEM tasks nurture essential dispositions for long-term STEM learning.

The integration of STEM into early childhood is also closely tied to the broader framework of 21st-century competencies. Skills such as collaboration, communication, creativity, critical thinking, and digital literacy are increasingly seen as indispensable in today's complex, technology-driven societies (Zviel-Girshin & Rosenberg, 2025). Within this framework, inquiry-based and play-based learning emerge as essential components of high-quality STEM education. Play-based learning, characterized by active engagement, open-ended exploration, and peer interaction, supports sophisticated forms of scientific and mathematical reasoning, including hypothesis testing, idea sharing, and examination of cause–and–effect relationships (Nergard, 2023).

Current research converges on the view that early childhood represents a critical window for establishing the foundational habits of mind that underpin later scientific reasoning, mathematical thinking, and problem-solving. Syntheses of empirical evidence, particularly the work of Brenneman, Lange, and Nayfeld (2019), demonstrate that developmentally appropriate STEM experiences in the early years foster inquiry, curiosity, cognitive flexibility, and persistence—dispositions that have long-term implications for how learners approach complex and unfamiliar problems. These findings suggest that the value of early STEM education extends far beyond the acquisition of discrete skills or preparatory knowledge. Instead, high-quality, integrated STEM environments shape children's long-term learning trajectories by nurturing adaptive, exploratory, and analytically oriented ways of thinking.

Inquiry-Based STEM Education in Early Childhood: Models, Processes, and Developmental Outcomes

The inquiry-based STEM approach positions children's innate capacities for curiosity, questioning, and exploration as the starting point of learning, thereby shaping the entire learning process around the child (French, 2004; Dilek et al., 2020). Learning begins not with abstract concepts but with concrete, real-world problems that children encounter in their everyday lives (Wang & Chen, 2025). Thus, the learning process becomes meaningful and contextual for children, allowing them to connect new knowledge with their own experiences directly. Pedagogical models used to implement inquiry-based learning effectively in STEM education include the 5E instructional model, the engineering design process, and specific inquiry cycles.

The 5E Instructional Model

The 5E instructional model holds strategic importance in preschool STEM education because it provides an inquiry-based pedagogical framework that aligns with the ways young children make sense of the world (Dilek et al., 2020; Lin et al., 2021). The model assumes that learners actively construct knowledge by comparing and testing new ideas against their existing conceptions (Desouza, 2017). It provides a structure highly suitable for STEM pedagogy, as it places children's innate abilities—curiosity, inquiry, and exploration—at the center of the learning process (Dilek et al., 2020). By using this model, preschool teachers can create enriched learning environments that support children's scientific process skills and motivation toward science (Dilek et al., 2020). Its structured steps enable children to acquire new knowledge through concrete experiences and deepen their learning by applying this knowledge to new situations (Dilek et al., 2020). In this context, a detailed examination of the model's phases clarifies its potential within preschool STEM education.

The Phases of the 5E Model and Examples of Implementation

The 5E instructional model consists of five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation (Dilek et al., 2020; Lin et al., 2021). Although these phases are often presented linearly, the model is most effectively used as a cyclic structure (Desouza, 2017). Each phase fulfills a specific pedagogical function within the learning process, and together they form a coherent whole that deepens conceptual understanding (Desouza, 2017). The model is built upon concrete, hands-on activities that support children's learning through active participation (Dilek et al., 2020).

The purpose of the *Engagement* phase is to capture children's attention, spark their curiosity, and activate their prior knowledge (Desouza, 2017; Lin et al., 2021). In this phase, the teacher uses various strategies to trigger children's curiosity and draw on what they already know (Dilek et al., 2020). For example, the teacher may employ a narrative-based approach by posing questions related to a scientific concept embedded in a story (Dilek et al., 2020). Alternatively, the teacher may show a closed box and ask children to predict what might be inside, creating a concrete, mystery-laden curiosity element (Desouza, 2017).

The *Exploration* phase is a process in which children investigate a scientific concept through hands-on experiences (Dilek et al., 2020). During this phase, children interact directly with materials and learn through discovery while working collaboratively (Desouza, 2017). This phase may take the form of a structured activity in which children test a specific concept using concrete materials or a more open-ended discovery walk in a natural environment (Desouza, 2017; Dilek et al., 2020). For example, while exploring the concept of sinking and floating, children begin by predicting whether objects such as a ping-pong ball, sponge, marble, or key will sink or float and record their predictions on a chart (Dilek et al., 2020). They then place the objects into water, observe what happens, and compare the outcomes with their predictions.

The *Explanation* phase provides a platform for children to express in their own words the experiences and observations they gained during exploration (Desouza, 2017; Dilek et al., 2020). During this process, the teacher introduces new vocabulary and scientific terminology, helping children make sense of their experiences and develop conceptual understanding (Desouza, 2017; Lin et al., 2021). This role allows the teacher to build a bridge between children's concrete explorations and the abstract language of science (Desouza, 2017). For instance, after learning through direct experience why a marble sinks, children articulate their observations in their own words (Dilek et al., 2020).

The *Elaboration* phase is where children apply their newly acquired conceptual knowledge to different and new situations, expanding and reinforcing what they have learned (Desouza, 2017; Lin et al., 2021). This phase aims to support the transfer of knowledge and its use in solving more complex problems (Dilek et al., 2020). The process may include elements of the engineering design cycle (Dilek et al., 2020). For example, when the teacher presents the problem "How can we transport toy cars to the other side of the water container?", a child might suggest, "We can use a boat" (Dilek et al., 2020). Having learned about sinking and floating, the children use this knowledge to design a boat. If their initial cardboard boat becomes damaged because the material is not water-resistant, they analyze the situation and improve their design (Dilek et al., 2020).

The *Evaluation* phase is a stage in which both children assess their own understanding and teachers evaluate the learning process (Desouza, 2017; Lin et al., 2021). Children reflect on the knowledge and skills they have acquired, while teachers assess learning outcomes through observations (Desouza, 2017). For example, children test whether the boats they built can carry toy cars; if the test reveals failure, groups discuss weaknesses in their designs and redesign their boats accordingly (Dilek et al., 2020).

The Engineering Design Process (EDP)

Using a structured framework such as the Engineering Design Process (EDP) in preschool STEM education holds strategic importance (Lin et al., 2021). Rather than a rigid, linear sequence of steps, the EDP should be understood as a cyclical and iterative process that encourages persistence and continuous improvement (Ültay & Aktaş, 2020). Although various models exist in the literature, a pedagogically sound framework for preschoolers can be synthesized from the five-step process (Ask, Imagine, Plan, Create, Improve) and Bers's (2018) cyclical model (ask, imagine, plan, create, test and improve, share) (Greca Dufranc et al., 2020; Lin et al., 2021). This synthesis presents six interconnected phases:

1. Ask / Define the Problem

This initial phase involves identifying a real-world problem or need (Lin et al., 2021). The process varies according to preschoolers' developmental levels, including narrative contexts that create emotional engagement (e.g., an animated story), spontaneous inquiries stemming from children's natural curiosity, or authentic challenges in the immediate learning environment (Ültay & Aktaş, 2020; Damjanovic & Ward, 2024; Wu et al., 2025). For example, a cartoon featuring an animal struggling to carry eggs serves as a motivating problem scenario (Ültay & Aktaş, 2020), while algae forming in a classroom fish tank becomes a catalyst for designing a water-filtration system (Wu et al., 2025). This phase aligns with the "Engage" phase of the 5E model, where teachers attract children's attention and help transform emerging questions into testable challenges (Dilek et al., 2020; Greca Dufranc et al., 2020).

2. Imagine

This divergent-thinking phase allows children to brainstorm freely and generate different solution ideas (Lin et al., 2021). The focus is on the diversity and originality of ideas rather than feasibility (Greca Dufranc et al., 2020). For example, children brainstorm various possible designs before selecting materials to create a device for carrying eggs safely (Ültay & Aktaş, 2020).

3. Plan

In this convergent phase, children narrow down the ideas generated during brainstorming, choose the most promising solution, and develop a concrete action plan (Lin et al., 2021). For preschoolers, these plans often take the form of drawings, sketches, or simple diagrams (Damjanovic & Ward, 2024; Ültay & Aktaş, 2020). Such visual plans help children organize their thoughts and guide the construction phase (Wu et al., 2025).

4. Create

This stage involves implementing the plan and constructing a prototype (Lin et al., 2021). Cognitive planning merges with kinesthetic experience as children manipulate materials—testing their properties and confronting real-world challenges while turning two-dimensional plans into three-dimensional structures (Ültay & Aktaş, 2020; Desouza, 2017). Examples include constructing a boat with various materials to transport toy cars across water (Dilek et al., 2020) or creating a functioning water filter for an aquarium (Wu et al., 2025).

5. Test & Evaluate

This critical stage highlights the empirical nature of engineering: children assess whether their designs effectively solve the original problem (Dilek et al., 2020). They learn that a design's success depends on objective results measured against the criteria of the initial problem (Ültay & Aktaş, 2020). For example, children test whether their boats sink while carrying toy cars (Dilek et al., 2020).

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6. Improve & Redesign

This final phase reflects the cyclical nature of engineering and reinforces the idea that failure is not an end but an opportunity for learning (Ültay & Aktaş, 2020; Lin et al., 2021). Children analyze flaws in their designs and improve them, fostering a growth mindset (Torres-Crespo et al., 2014, as cited in Wu et al., 2025). Studies document that when some boats sank during testing, groups redesigned their models—for example, by adding waterproof bags (Dilek et al., 2020).

The success of the Engineering Design Process in preschool depends largely on teachers' pedagogical approach and the design of the learning environment (Wang & Chen, 2025; Wu et al., 2025). In this process, the teacher shifts from being a traditional transmitter of knowledge to a facilitator, guide, supporter, and collaborator (Wang & Chen, 2025). Teachers should employ various questioning strategies to redirect attention, probe thinking, and encourage deeper inquiry rather than providing direct answers (Chen & Tippett, 2022). A rich learning environment with diverse, accessible, and open-ended materials enables children to explore and test their ideas freely (Wu et al., 2025; Damjanovic & Ward, 2024). Learning centers also serve as an effective strategy to facilitate this environment (Chen & Tippett, 2022). Research shows that the Engineering Design Process enhances children's problem-solving skills (Dilek et al., 2020; Lin et al., 2021), collaboration and communication (Wang & Chen, 2025; Ültay & Aktaş, 2020), and critical and creative thinking (Wang & Chen, 2025).

Specific Inquiry Cycles

More focused inquiry cycles designed to support the hands-on understanding of specific science concepts also exist. The PD/OQ/DET Model, developed as an extension of the POE (Predict-Observe-Explain) inquiry model, includes the steps Predict, Do/Observe, Quiz/Discuss, and Explain/Transfer (Hong et al., 2020). For example, in the "DO RE MI with Cups" activity, children are first asked to predict the sounds produced when tapping cups with different water levels (Predict) and then to tap the cups themselves to observe the sounds (Do/Observe) (Hong et al., 2020). The teacher initiates a discussion by asking why the sounds differ (Quiz/Discuss). Finally, children learn how water level affects sound frequency and are asked to apply this information to other real-life examples (Explain/Transfer) (Hong et al., 2020). This model places particular emphasis on hands-on action and the transfer of knowledge to new contexts (Hong et al., 2020).

Effects of Inquiry-Based STEM Education on Children

Children naturally develop fundamental scientific process skills during the learning process, including observing, comparing materials and outcomes, predicting, collecting data, classifying objects based on their properties, and communicating their findings with peers and teachers (Dilek et al., 2020; Chen & Tippett, 2022). These skills are systematically supported through structured pedagogical models. For example, observation and comparison skills are used extensively in the Exploration phase of the 5E model, while communication skills are central to the Explanation phase.

Children engage in designing solutions to real-world problems, creating prototypes, testing them, and improving them based on results. This cyclic process significantly enhances problem-solving and engineering thinking skills (Lin et al., 2021; Wang & Chen, 2025). Scientific concepts—such as force, balance, and density—become more deeply understood through concrete, hands-on experiences. Children develop the ability to transfer knowledge gained from one activity to new and different situations (Hong et al., 2020; Wang & Chen, 2025).

Inquiry-based STEM education has a transformative impact on children's attitudes toward learning and science. Research shows that children who participate in such activities exhibit marked increases in motivation, curiosity, and interest in science. They begin to perceive science as "fun," "easy," and "exciting" (Dilek et al., 2020; Lin et al., 2021). As children test their own ideas and observe outcomes, their self-confidence grows, and they begin to develop a positive academic identity, seeing themselves as "lifelong STEM learners" (Damjanovic & Ward, 2024; Lin et al., 2021).

Most inquiry-based STEM activities are conducted as group work or collaborative projects. This social environment provides rich opportunities for developing social skills. While working toward a shared goal—such as building a boat (Dilek et al., 2020) or completing a treehouse project (Damjanovic & Ward, 2024)—children naturally learn teamwork, expressing ideas effectively, sharing responsibilities, and resolving conflicts (Wang & Chen, 2025; Dilek et al., 2020). Ultimately, the inquiry-based STEM approach fosters holistic development, enhancing not only cognitive abilities but also children's affective and social competencies.

Evaluation of Preschool Education Models in the Context of STEM

The importance of STEM (Science, Technology, Engineering, and Mathematics) education in early childhood has been steadily increasing, as this period is characterized by heightened curiosity, exploratory behavior, and rapid development of foundational cognitive skills. This critical stage marks the emergence of problem-solving, inquiry, and collaboration tendencies, laying the groundwork for later STEM-related ways of thinking. In this context, influential early childhood approaches such as Reggio Emilia, Montessori, Waldorf, and Project-Based Learning (PBL) provide strong pedagogical foundations that support analytical thinking, creativity, and exploration-based learning from an early age. In this section, the significance and place of these approaches in relation to STEM education will be highlighted.

1. Reggio Emilia and STEM Education

The Reggio Emilia approach, developed in the post–World War II period under the leadership of Loris Malaguzzi, is a child-centered educational philosophy grounded in constructivism, collaboration, and democratic participation. In this model, the child is viewed as competent, curious, and capable of co-constructing knowledge through interaction with peers, adults, and the environment (Edwards, Gandini, & Forman, 2012). The Reggio philosophy emphasizes the "hundred languages of children," underscoring the belief that children express ideas through multiple symbolic systems such as art, movement, construction, and dramatic play (Malaguzzi, 1998). With its project-based structure and emphasis on inquiry and collaboration, the Reggio Emilia model has become one of the most influential contemporary early childhood approaches worldwide.

The Reggio Emilia–inspired approach provides a compelling pedagogical foundation for early childhood STEM education because its inquiry-driven and project-based structure aligns closely with the epistemic practices of science and engineering. In this model, children are viewed as capable researchers whose investigations emerge from authentic questions, while *provocations* and a materially rich environment function as catalysts for hypothesis formation, experimentation, modeling, and multimodal representation. The Reggio emphasis on the "hundred languages" allows children to externalize scientific and mathematical thinking through diverse symbolic forms, supporting core STEM processes such as observation, data collection, spatial reasoning, and iterative problem-solving. As highlighted in the iSTEM Rope Model, these pedagogical features position Reggio Emilia not only as compatible with integrated STEM learning but as a powerful lens for conceptualizing and enacting high-quality EC-iSTEM practice (Hachey & Mehta, 2024).

2. Montessori and STEM Education

Montessori pedagogy is a structured yet self-directed learning approach grounded in the principles of sensory experience, independence, and the child's active construction of knowledge within a carefully prepared environment. This method centers on children's natural curiosity, developmental sensitivities, and their capacity to build understanding through hands-on interaction with didactic materials. In Montessori classrooms, science, mathematics, and cultural concepts are concretized through sensory materials and gradually transitioned toward abstraction, providing a robust foundation for the development of early scientific reasoning (Livstrom, Szostkowski, & Roehrig, 2019).

Recent empirical work demonstrates a high degree of alignment between Montessori pedagogy and early STEM integration. Livstrom et al. (2019) highlight that exploration, construction, problem-solving, iterative refinement, and manipulative-based engagement in Montessori environments mirror core processes of integrated STEM learning. Fehr's (2020) action research in a Montessori early childhood classroom similarly shows that introducing engineering- and technology-oriented materials increases children's inquiry behaviors and engagement with scientific practices. These findings suggest that essential Montessori features such as the concrete-to-abstract progression, independent work cycles, self-regulation, and sequenced learning materials intrinsically support engineering design thinking, scientific inquiry, and mathematical reasoning.

At a broader systems level, recent international analyses confirm the structural compatibility between Montessori pedagogy and STEM/STEAM frameworks. Slipukhina et al. (2024), in their examination of STEM–STEAM–STREAM and Montessori centers across Ukraine, argue that Montessori environments naturally incorporate many of the pedagogical markers of integrated STEM education, including hands-on inquiry, open-ended design tasks, and student-driven exploration. Their findings show that Montessori centers often function as de facto STEM-oriented spaces even without formal STEM branding, due to their emphasis on autonomy, sensorial exploration, and multi-domain problem-solving. This macro-level evidence reinforces the idea that Montessori pedagogy not only aligns with but also often operationalizes the foundational principles of contemporary STEM/STEAM education.

3. Waldorf and STEM Education

The Waldorf approach, grounded in Rudolf Steiner's anthroposophical framework, offers a holistic and developmentally attuned model of early education in which rhythm, imagination, nature immersion, and artistic expression form the structural basis of learning. Rather than accelerating formal academics, Waldorf early childhood programs emphasize predictable rhythms, rich sensory experiences, storytelling, movement, and extended engagement with open-ended natural materials (Tyson, 2023). Contemporary analyses highlight that these practices daily and seasonal rhythms, outdoor immersion, and arts-integrated tasks, continue to align with modern understandings of child development, supporting balanced growth across cognitive, social, and emotional domains (Taplin, 2024). In this sense, Waldorf creates a nature-anchored and aesthetically enriched learning ecology that prioritizes lived experience as the foundation for later conceptual development.

Although Waldorf education does not explicitly identify itself with STEM or STEAM agendas, empirical research indicates that its inquiry-rich, observation-centered, and phenomenological approach naturally cultivates scientific dispositions. In a large-scale comparative study, Salchegger et al. (2021) found that Waldorf students exhibit significantly higher motivation and interest in science than their peers, a pattern attributed to the model's emphasis on careful observation, engagement with natural environments, and exploratory encounters with phenomena. These characteristics, attentiveness, persistence, and sensory-based inquiry, mirror foundational components of scientific thinking and early STEM learning. Furthermore, recent STEAM scholarship underscores that holistic models integrating nature, arts, creativity, and active exploration can strengthen children's readiness for interdisciplinary learning; Sachpatzidis et al. (2022) argue that STEAM education thrives in environments where observation, hands-on activity, critical thinking, and aesthetic engagement intersect—conditions that closely parallel the structural ethos of Waldorf early childhood pedagogy. Together, these findings suggest that while Waldorf does not frame its curriculum through STEM terminology, its pedagogical design organically supports many of the dispositions, habits of mind, and exploratory processes central to early STEM/STEAM learning.

4. The Project Approach and STEM Education

Project-Based Learning (PBL) is an inquiry-oriented and interdisciplinary pedagogical approach in which learners investigate meaningful and authentic problems over extended periods, constructing knowledge through iterative cycles of exploration, design, and reflection. In this model, children participate in activities that require them to ask investigable questions, gather and interpret data, test and refine ideas, construct models, and communicate their reasoning, positioning them as active contributors to the learning process. According to Chen and Hui (2024), PBL is one of the most adaptive and effective frameworks for integrating complex skills such as problem solving, collaboration, and computational thinking, because it facilitates sustained engagement with interdisciplinary ideas and authentic problem contexts.

Grounded in constructivist and sociocultural theory, PBL creates developmentally appropriate opportunities for young children to refine their reasoning through guided exploration and social interaction, making it particularly suitable for early childhood education.

In early childhood STEM and STEAM education, PBL offers an age-appropriate structure through which young children can participate in the epistemic practices of science, engineering, mathematics, and integrated design. Chen and Tippett (2022) demonstrated that project-based inquiry enabled preschool children to engage meaningfully in processes such as observation, prediction, investigation, measurement, modeling, and multimodal documentation, indicating that young learners can participate in scientific inquiry when project structures guide their engagement with STEM concepts. Complementing this evidence, Wang et al. (2025) showed that project-based STEM tasks, particularly hands-on engineering challenges, strengthened children's abilities in problem posing, collaborative work, iterative design reasoning, and interdisciplinary thinking. In the context of STEAM, Peng and Su (2024) found that a semester-long project-based STEAM exploration improved preschoolers' motor imagination and creative thinking, suggesting that extended arts-integrated design projects support innovation-related skills within STEM-rich learning environments. Taken together, these studies demonstrate that PBL supports the aims of early childhood STEM and STEAM education by fostering inquiry, iterative design thinking, creativity, and evidence-based reasoning through meaningful child-centered investigations.

In conclusion, implementing STEM and STEAM approaches in early childhood is essential, as it provides young learners with an early foundation for holistic, inquiry-driven, and hands-on modes of thinking. As demonstrated in research on STEM–STEAM–makerspace environments, such learning contexts offer powerful pedagogical tools that promote creativity, collaboration, and problem-solving during the earliest stages of development (Johnston et al., 2022). Empirical studies further show that activities involving engineering design, robotics, and digital STEM applications make meaningful contributions to the development of core cognitive competencies in young children (Wan et al., 2021). Moreover, sustainability-oriented early STEM/STEAM experiences have been shown to cultivate curiosity, observation, systems thinking, and scientific reasoning from a very young age (Rodrigues-Silva & Alsina, 2023). Taken together, early childhood STEM education emerges as an indispensable component of contemporary educational practice, as it strengthens the cognitive foundations that support long-term academic success and provides an early entry point into lifelong learning.

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SECTION 3.
SCIENCE AND TECHNOLOGY IN CONTEMPORARY EDUCATION

THE IMPORTANCE OF OUT-OF-SCHOOL LEARNING ENVIRONMENTS AND REFLECTIONS ON SCIENCE EDUCATION

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INTRODUCTION

Science education that extends beyond the traditional school roof and classroom walls is reshaping the way students interact with the natural world. Today's educational philosophy requires that learning extend beyond the confines of school desks to various environments that offer rich experiences that support students' curiosity and inquiry skills. Out-of-school learning environments encompass many different areas, including museums, science centers, zoos, botanical gardens, nature parks, industrial facilities, and even the local environment. These environments make learning more meaningful, permanent, and motivating by offering students the opportunity to experience abstract scientific concepts in concrete, real-life contexts. This section of the book will emphasize the importance of out-of-school environments in the learning process and science education, touching on the concept of lifelong learning.

A Brief Overview of Learning and Its Types

Today, students' interest in schools is steadily declining. The main reasons for this situation include the fact that schools, as educational institutions, are considered ordinary, lessons are overly theoretical, and there is no connection between what is taught in class and daily life. In addition, weak social relationships in classrooms, the competitive environment, and the pressure and anxiety caused by exam-oriented education are among the reasons for this situation (Şanlı et al., 2015). Developments in science and technology or environmental factors also contribute to the decline in interest in school. For example, the increase in social media and virtual game content and the presentation of this content in more appealing ways reduces students' interest and motivation in educational institutions and lessons, negatively affecting the learning process (Sağır & Okutan, 2022).

The purpose of education systems is not only to produce knowledgeable individuals. Developing individuals' skills and ensuring the continuity of their desire to learn are among the goals of education (Nelson, 1981). Enabling individuals to express themselves correctly and appropriately, to possess the skills necessary to continue their lives as individuals capable of responding to today's needs, and, in short, to enable them to realize their full potential are among the outcomes that education systems seek to achieve (Adabaş, 2016; Yavaş et al., 2021).

What is learning?

Defining the concept of learning is a complex process. When it comes to the concept of learning, it is observed that each society or state has its own unique definition (Colardyn & Bjornavold, 2005). In its most general definition, learning can be described as a permanent behavioral change resulting from an individual's interaction with their environment (Senemoğlu, 2015). In this technological age we live in, we encounter new discoveries or inventions every moment. Every second new knowledge is produced and new technologies enter our lives. In order to keep pace with this change and development, we live in a state of constant need for learning. This situation necessitates the structuring of the learning process as a lifelong process independent of specific boundaries (Colardyn & Bjornavold, 2004). The emphasis on lifelong learning has necessitated the restructuring of the entire education system and the development and integration of types of education outside of formal education into the system (Güleç et al., 2012). Lifelong learning is the continuous development of the knowledge, skills, and behaviors that individuals possess throughout their lives. In this context, the knowledge, skills, attitudes, and behaviors that individuals acquire in their daily lives are addressed within the scope of lifelong learning (Laal & Salamati, 2012).

What is Life-Long Learning?

In the information age, where change and development affecting individual and social life are taking place in every field, societies strive to continuously improve themselves and become better versions of themselves in order to keep up with and adapt to this development and change. The rapid increase in information has led to the reshaping of social systems. Education is a system that is constantly changing and evolving with this reshaping. It is only possible for individuals to become sufficiently equipped with the knowledge, skills, attitudes, and behaviors appropriate for today's world, to keep up with the constantly changing and evolving global dynamics, and to adapt to these changes and developments through a quality education process that begins at an early age and continues throughout life (Coolahan, 2002).

The concept of education has been defined differently by different researchers at different times. Plato described education as the process of bringing the individual to the highest level of maturity. J. J. Rousseau, on the other hand, viewed education as an art. In this definition, the concept of art refers to the art of raising children well and making them human beings.Fidan, meanwhile, approaches education as the process of raising individuals within specific goals. According to Tyler, education represents a process. In this process, individuals change their own behavior patterns. Spencer, on the other hand, views education as a process of preparation for life (Çıkılı, 2010).

Based on these definitions, it can be seen that education generally refers to the process of consciously and purposefully changing behavior in a desired direction through one's own experiences. Education can be described as the process of bringing about desired changes and behavioral modifications in individuals and integrating them into society, shaped by the social structure. The behavioral changes referred to in definitions of education are those that will positively affect individuals and the societies in which they live (Kültekin, 2006; Tezcan, 1985).

Individuals need to continuously learn in order to acquire new knowledge and skills. This situation has led to the emergence of the concept of lifelong learning. Lifelong learning is defined as the process of self-development in all areas through learning experiences gained through interactions with the social environment in which individuals live (Jarvis, 2007). In other words, lifelong learning is the ability to adapt and keep up with rapidly changing and developing fields, to access necessary data through different channels, and to evaluate this data and information (Medel-Añonuevo et al., 2001). The term lifelong learning, one of today's widely used concepts, was first discussed internationally in the 1970s. The report titled "Learning to be: the world of education today and tomorrow," known as the "Faure Report," emphasized the concept of lifelong education. Published by UNESCO in 1972, this report recommended that societies restructure their education systems in accordance with the requirements of lifelong learning. The report emphasized the importance of ensuring the continuity of education (Miser, 2020; UNESCO, 2013).

Delors (1993) discussed the four fundamental goals of lifelong learning. These four fundamental goals are listed as learning to know, learning to do, learning to be, and learning to live together. Lifelong learning is a concept that encompasses not only these four fundamental functions, which include processes such as individual fulfillment, active citizenship, adaptability to working life, and socialization, but also numerous interconnected goals. In this context, it would be incorrect to interpret lifelong learning solely within professional and economic boundaries (Jarvis, 2010). The OECD (1996) defines lifelong learning as a process that continues from early childhood until the end of an individual's life. According to this definition, the lifelong learning process is not limited to formal educational institutions such as schools and universities; it also encompasses informal learning that takes place at home, at work, and in short, in all areas of life.

UNESCO (2014) defines lifelong learning as a process based on democratic, liberating, and humanistic values. According to this definition, the concept of lifelong learning encompasses all learning activities carried out through various methods in formal, informal, and non-formal settings to meet the different needs and demands of all individuals, regardless of age. With the adoption of the concept of lifelong learning, the concepts of informal and non-formal learning, which encompass learning outside the school environment, have gained importance. In their study, Knapper and Cropley (2000) stated that lifelong learners are individuals who can continue learning in formal and informal settings. Arıkan et al. (2024) emphasized the continuity of learning throughout life and stated that out-of-school learning environments are important tools that support this process.

In-School and Out-Of-School Learning

The concept of learning occurring independently of time and place has led to the adoption of the idea of moving beyond the classroom and school environment. Learning that takes place outside of school settings plays a significant role in lifelong learning (Ustabulut, 2021). The concept of lifelong learning encompasses all forms of learning, including formal, informal, and non-formal. This understanding has necessitated the integration of learning activities and strategies aimed at out-of-school learning environments into the education and teaching system (Tösten, 2022).

Learning that takes place in schools and similar educational institutions is considered formal learning, while learning that occurs outside the school setting is considered out-of-school learning (Gerber et al., 2001). Classifying out-of-school learning as informal and non-formal helps us understand the nature of these learning experiences (Eshach, 2007). The environments where out-of-school learning takes place are those where students' learning experiences outside of formal education occur. Eshach (2007) presented the non-formal and informal learning environments that constitute out-of-school learning with a visual aid.

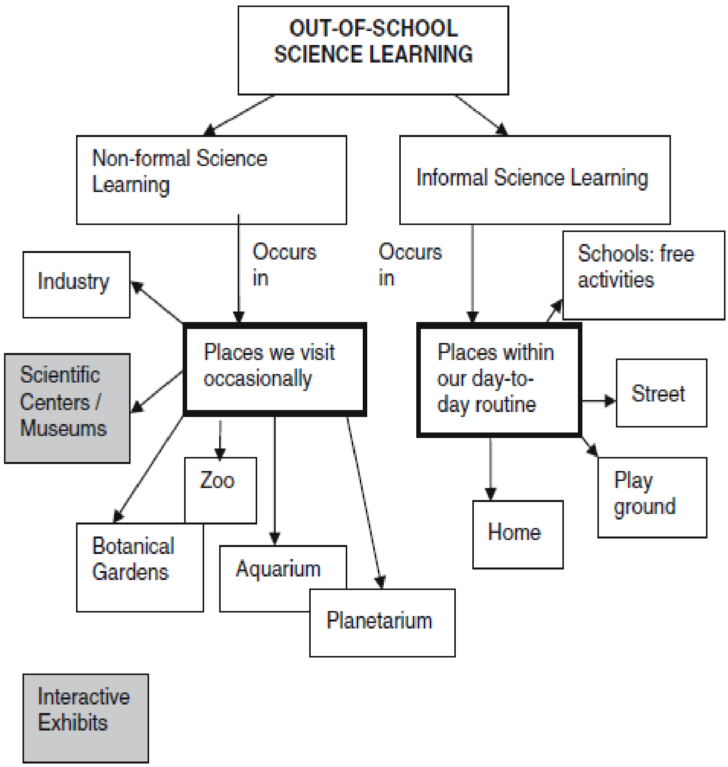

Figure 1. *Non-Formal and Informal Learning Environments*

In this visual presented by Eshach (2007), non-formal learning environments refer to areas where structured and planned learning takes place to support formal education, while informal learning environments are places where spontaneous learning occurs, essentially unplanned and unstructured learning. The learner's home, playgrounds, and streets can be given as examples of areas where informal learning takes place (Tal & Morag, 2009). Today, the most popular environments for out-of-school learning include museums and virtual museums, science centers, zoos, botanical gardens, health institutions, national parks, natural monuments, libraries, planetariums, aquariums, industrial establishments, science cafes, parks, archaeological sites, ancient cities, and art galleries. (Metin Göksu & Sömen, 2022; Laçin Şimşek, 2020; Saraç, 2017; Şahin & Özkan, 2023; Şen, 2023; Uçarçelik, 2022).

As one of the most commonly used out-of-school learning environments, museums contribute to the development of many skills through the objects they contain and their unique atmosphere. Museums, which offer an active participation experience for learners, facilitate a learning process that appeals to multiple senses (Kara et al., 2020). Virtual museums, which have become popular in recent years, are created by transferring physical museums into a virtual environment (Özer, 2016). Virtual museums can be visited at any time, regardless of time and place, allowing individuals to benefit from museums that they would otherwise be unable to visit (Tepecik, 2007). Science centers bring individuals from different segments of society together with science, offering interactive teaching approaches in their unique areas of activity. Science centers aim to encourage learners to explore and experiment, while also explaining the importance of science and technology for societies (Karabulut et al., 2024). Zoos are out-of-school learning environments that provide information about natural life and offer opportunities for active participation and learning by doing and experiencing. Zoos, which are very successful in attracting the interest and attention of learners, serve to increase the retention of information by presenting concrete examples of abstract concepts (Christoph et al., 2007; Müller, 2006; Pace & Tesi, 2004). Botanical gardens are places where botanical knowledge, various plant species, interspecies relationships, and information about biodiversity are presented, establishing a special bond between people and plants. Botanical gardens raise awareness, particularly on environmental education and sustainability issues (Drayton, 2000; Kubat, 2018; Nuhoğlu, 2020).

Aquariums are facilities that display living species belonging to aquatic ecosystems. Aquariums provide an opportunity to exhibit many species that are often impossible to observe in their natural habitats. In this context, visitors can understand the theoretical knowledge they have learned about living species by seeing real-life examples (Cıngıl Barıs & Acar Sesen, 2020). Planetariums are technologically advanced spaces built with the aim of helping learners correctly structure their knowledge about space and astronomy. Planetariums use real scientific data and reflect the sky realistically (Thornburgh, 2017). In this context, they play an extremely important role in concretizing abstract concepts and increasing the permanence of information (Bozdogan & Ustaoglu, 2016).

National parks are defined as natural areas possessing national and international natural and cultural resources, compatible with environmental and cultural thinking, and offering numerous uses such as science, education, recreation, conservation, leisure, and tourism (Official Journal, 1983). National parks are areas that reflect the historical, cultural, and natural values of their surroundings (Bakioglu, 2017). They are particularly effective out-of-school learning environments for environmental education (Lugg & Slattery, 2003). Libraries, another out-of-school learning environment, served to bring printed resources to the public in the past, but today, with the development of technology, they serve as more dynamic institutions. Libraries, which provide access to both written and electronic resources, offer opportunities for cultural development through social interaction and learning ways to access information. With the proliferation of online libraries, individuals can access information whenever and wherever they want (Cukadar & Celik, 2003; Dalkıran, 2014; Ersoy & Yılmaz, 2009).

Formal learning

Formal learning refers to learning that takes place within a specific time frame, with the aim of achieving desired goals, through education provided by experts in their field within a predetermined plan and program, in specific locations such as schools (Lacin Simsek, 2011). The formal learning process involves a number of elements, such as educational institutions and teachers. The formal learning process refers to an organized process in which activities determined by teachers are used to achieve learning objectives that are sequentially defined within an educational program. In terms of these characteristics, the literature interprets the formal learning process as a teacher-centered process (Dovey & Fisher, 2014; Garner et al., 2015; Radović & Passey, 2016).

In formal processes, institutions and educators operate according to a schedule. In this hierarchical system, educators follow a set of direct teaching behaviors. Student participation is mandatory in formal learning systems (Johansson, 2003; Moldovan & Bocoş-Binţinţan, 2015). In formal learning processes, the learning process is consciously carried out by teachers and learners (Cain & Chapman, 2014; Yeasmin et al., 2020). As a result of the formal learning process, learners are usually rewarded with a qualification certificate such as a diploma or certificate. In this context, these reward-like certificates are of great importance in formal learning processes (Ivanova, 2016; Pienimäki et al., 2021).

It is believed that formal learning processes place greater emphasis on cognitive achievements (Romi & Schmida, 2009). This stems from the fact that formal learning processes focus on conceptual knowledge rather than procedural knowledge, which includes competencies, techniques, and skills (Malcolm et al., 2003). There are clearly defined characteristics and established features of learning that will take place in the formal learning process. Learning is purposeful and planned. The learning process takes place in formal educational institutions with a teaching program. Attendance may be required in learning environments. Formal learning tends to be more cognitive in quality. Socialization may not be a requirement for learning. In formal learning processes, learning motivation can be supported by visible external factors such as exam scores (Johnson & Majewska, 2022).

Formal learning processes are carried out through official curricula. These curricula are teaching programs that systematically include many factors such as the desired goals, objectives, lesson plans, content to be learned, learning methods and strategies, learning equipment, and the evaluation process. Learning is achieved through the implementation of this curriculum in classrooms by official institutions (Alnajjar, 2021; Ayçiçek, 2021; Bamkin, 2020; Casey, 2017). In short, the formal learning process refers to an educational process organized through a curriculum (Karademir, 2018).

The formal learning process contributes significantly to the education system. Formal learning is an appropriate method for ensuring that the learning process continues at certain standards across different fields. For example, it will bring about many equalities, such as the same curriculum being followed in schools located in all regions of a country. This situation ensures the controllability of the education system. This feature also ensures that improvement efforts in the learning process are carried out at a certain standard (Cain & Chapman, 2014; Läänemets et al., 2018). Formal education ensures the accumulation of knowledge transmitted through generations in the learning process. Thus, each new generation possesses more conceptual knowledge (Malcolm et al., 2003; Morgan, 2015). Considering that formal education adheres to a specific and mandatory curriculum, adherence to the curriculum actually highlights the strength of formal education in ensuring equality in the education system at the national level. With a standardized curriculum, all individuals at the same educational level across the country can continue their education with the same curriculum and information (Zhao et al., 2023). Furthermore, formal education has diverse and reliable assessment and evaluation methods (Bjørnåvold, 2000).

The implementation of formal education based on a formal curriculum may cause some learners to have a negative attitude towards formal education. This situation also leads to the belief that formal education is not suitable for all learners. This situation presents a disadvantage. For example, learners may perceive formal education as a rigid, teacher-led learning process (Gage et al., 2020; Melnic & Botez, 2014). Another disadvantage of this type of learning is that formal education processes are knowledge-heavy and lack real-life experience (Cain & Chapman, 2014). Formal education may not be sufficiently effective in eliminating learners' misconceptions or non-scientific knowledge related to abstract concepts. In such cases, there is a need to concretize abstract concepts (Frappart & Frède, 2016). The fact that formal education systems are subject to an assessment criterion and that lesson times in the curriculum are fixed and limited may affect teachers' behavior towards students in the classroom. Teachers who are required to cover and complete a specific topic within a specific time frame may unintentionally disregard their students' motivation or participation in the lesson (McKay et al., 2013).

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Out-Of-School Learning

Informal learning

Piaget argues that knowledge is acquired through experience. Young children interpret concepts based on their own experiences. Collaboration and peer learning are of great importance in the process of gaining experience (Sevinç, 2009). Dewey opposed the idea that learning should be rigidly imposed by a specific leader. According to Dewey, learning occurs through experiences and interactions. In this context, the environments where learning takes place should be application-based (Bender, 2005). Vygotsky argues that young children's learning occurs as a result of their interaction with their environment. Initial learning occurs within the family, between individuals. Language is the mediator of this learning. Learning can occur anywhere there is interaction with the environment, through communication with different individuals (Berk, 2015). Bandura is considered the representative of social learning theory. Bandura argues that learning occurs in social environments through interaction, observation, or imitation of behavior. Learning can occur whenever there is interaction with the environment (Tatlıoğlu, 2021). These understandings highlight the importance of informal learning. Miser (2011) emphasizes that informal learning is the oldest and most widespread form of learning, used in the process that has continued from the beginning of human existence to the present day.

Informal learning can be defined as learning that occurs naturally throughout the life process. This learning may result from daily experiences and interactions with the environment. In this context, it is not systematic or regular learning like formal learning (Coombs & Ahmed, 1974). Informal learning refers to a lifelong process. In this context, it is part of life. Research shows that the vast majority of learning acquired by individuals throughout their lives is the result of informal learning (Cainey et al., 2012; Latchem, 2018). Informal learning encompasses tacit knowledge that is not deliberately sought by the learner. Since it does not involve a deliberate learning process, the learner is often unaware that learning has taken place (Eraut, 2004).

Informal learning, which is not based on didactic approaches, can be facilitated by peers or experts. In the informal learning process, learning is embedded in a meaningful activity. The learner occupies a very important position in the process. In informal learning, the learning process is initiated by the learner and is supported by a need or problem (Bourke et al., 2018; Kral & Heath, 2013). Informal learning is not explicitly structured by external factors such as teachers, institutions, or parents (Alnajjar, 2021; Eisner, 1992). Voluntariness is fundamental in this type of learning (Garner et al., 2015). Informal learning does not require systematic organization (Norqvist & Leffler, 2017). It can take place anywhere, independent of location. This learning is situation-dependent. They are contextual. These learning experiences are shaped by the environment in which they occur (Filippoupoliti & Koliopoulos, 2014; Gloria et al., 2014). Informal learning is not primarily language-based like formal learning. These learning processes are more related to non-verbal behaviors such as trial and error, imitation, and modeling (Evans et al., 2015; Gower, 2012; Johansson, 2003; Kral & Heath, 2013).

Informal learning does not have specific linear goals. It can occur independently of time and place. There is no heavy emphasis on conceptual knowledge in this type of learning. Informal learning is not only cognitive but also emotional and behavioral in nature. There is no specific curriculum in the informal learning process. It usually occurs in response to a situation. The learner and the learner's needs are at the center of informal learning. Unlike formal learning, informal learning occurs through socialization (Johnson & Majewska, 2022).

Informal learning does not require a specific purpose or school boundaries. In this context, it can occur at any moment when individuals interact with life (Griffin, 1994). The flexibility of the informal learning process, which is not bound by specific routines, makes the learning process enjoyable and motivating (McKay et al., 2013). Informal learning systems, which represent a flexible process not bound by specific patterns, are processes that can shape learning in the context of the learner's personal needs (Wiebe et al., 2013).

Informal learning has a supportive effect on formal learning (Allaste et al., 2022). Since these learning processes are not subject to an evaluation process like formal learning, they may not occur at as high a concentration as formal learning. This situation sometimes results in individuals being unaware of the learning process (Hallam et al., 2018; Schugurensky, 2000). Informal learning, like formal learning, does not only encompass desired learning. As a result of informal learning, an individual may have acquired correct or incorrect knowledge as well as positive or negative behaviors (Görgen, 2014).

Non-formal learning

Non-formal learning is defined as learning that takes place outside of school boundaries, provided it is linked to a specific teaching program (Türkmen, 2010). Non-formal learning, like formal learning, is systematically planned and structured towards a specific goal in line with learning objectives (Allaste et al., 2022; Garner et al., 2015; Mok, 2011).

Non-formal learning is similar to formal learning in that it occurs within specific objectives, but it differs in that the learning process takes place outside the school setting. Non-formal learning has a reinforcing effect on formal education by providing opportunities for experiential learning (Batman, 2020). In this context, it provides opportunities for permanent and meaningful learning by establishing the relationship between the knowledge acquired in formal education processes and daily life (Ay et al., 2015). Non-formal learning is intentional learning (Tudor, 2013). The motivation for non-formal learning may be specific to the learners. Since non-formal learning is not subject to strict assessment processes like formal learning, it places less emphasis on formal qualifications (Malcolm et al., 2003; Ivanova, 2016).

Non-formal learning is application-based and encompasses various learning activities and practices. Therefore, it is closely related to the emotional and psychomotor domains rather than the cognitive domain. Non-formal learning focuses on acquiring skills, behaviors, and competencies rather than theoretical knowledge (Madjar & Cohen-Malayev, 2013; Młynarczuk-Sokołowska, 2022; Souto-Otero, 2021). When examining the structure and characteristics of non-formal learning, it is seen that these learning processes serve as a transition between formal and informal learning (Eshach, 2007).

Non-formal learning processes are attractive and engaging for most students due to their flexible structure (Bozdoğan & Ustaoğlu, 2016). Non-formal learning enables the concretization or experiential application of knowledge acquired through formal learning (Affeldt et al., 2018; Badger, 2021; Lee, 2012). Non-formal learning activities and events can make information more memorable (Frappart & Frede, 2016). The fact that non-formal learning activities offer opportunities for interactive learning shows that this interaction has a positive effect on the development of a set of social skills (Läänemets et al., 2018).

Non-formal learning, which has many benefits for the learning process, also has characteristics that can be interpreted as limitations or disadvantages. Non-formal learning encompasses a wide variety of activities and content. In these learning processes, the skills of the educator have an impact on the process. Therefore, these factors are a cause for concern in non-formal learning. The flexible structure of non-formal learning processes, which do not have a rigid curriculum, allows for activities and practices to take place in different forms and sometimes prevents the desired outcome from being achieved (Malcolm, et al., 2003). Determining whether non-formal processes are successful is not as clear and easy as it is in formal processes. The fact that the evaluation process is observation-based also makes it difficult to monitor the quality of the education provided (Powdyel, 2016).

As can be seen, although formal, non-formal, and informal learning share certain basic characteristics, each has its own distinct advantages, disadvantages, and limitations. Eshach (2007) compared formal, non-formal, and informal learning in terms of certain basic qualities in his study. Eshach (2007) summarized the similarities and differences between formal, informal, and non-formal learning in a table (Table 1).

Table 1. *Similarities and Differences Between Formal, İnformal, and Non-Formal Learning*

Formal Learning	Non-formal Learning	Informal Learning
Usually at school	At institution out of school	Everywhere
May be repressive	Usually supportive	Supportive
Structured	Structured	Unstructured
Usually prearranged	Usually prearranged	Spontaneous
Motivation is typically more extrinsic	Motivation may be extrinsic but it is typically more intrinsic	Motivation is mainly intrinsic
Compulsory	Usually voluntary	Voluntary
Teacher-led	May be guide or teacher-led	Usually learner-led
Learning is evaluated	Learning is usually not evaluated	Learning is not evaluated
Sequential	Typically non-sequential	Non-sequential

Out-Of-School Learning Environments and Science Education

As explained in the first section, learning that takes place under the school roof is referred to as formal learning, while learning that occurs in out-of-school environments is named non-formal or informal learning depending on the characteristics of the learning. In general terms, out-of-school learning is defined as learning that occurs outside of the learning acquired through lessons given under the school roof. In this context, the most general characteristic of these learning experiences is that they occur out of school (Janiuk, 2013; Tran, 2011). Out-of-school learning environments include everyday spaces such as parks, playgrounds, and homes, as well as designed environments such as museums and libraries (Fenichel & Schweingruber, 2010).

According to common belief, teaching in classroom settings is generally theory-heavy and lacks experience and implementation. The structure of science education requires learning experiences based on implementation and discovery (Braund & Reiss, 2006). In this context, for effective science education, learning environments outside of school must be synthesized and incorporated into teaching in a way that supports and reinforces learning within the school (Stocklmayer et al., 2010). Learning that takes place in out-of-school learning environments is important and necessary for the constructivist approach. The basic philosophy of the constructivist approach is to participate actively in the learning process, to be part of a social context, to learn by doing and experiencing, and to create meaningful learning (Ay et al., 2015; Bada, 2015).

The purpose of science as a discipline is not only to provide learners with theoretical knowledge. Another goal of science education is to equip learners with the competence to generate solutions to problems they may encounter in their daily lives (Okur, 2017). The mission of science education includes raising learners to be productive, scientifically literate individuals who use scientific process skills. All the competencies necessary for individuals to understand and make sense of the universe, the planet they live on, and nature are among the goals of effective science education (Türkmen, 2010).

As is well known, out-of-school learning environments provide individuals with opportunities for experience by appealing to different senses (Ertaş et al., 2011). The integration of out-of-school learning environments into science education enables learners to develop in cognitive, affective, and psychomotor domains. Additionally, they can relate the content learned in science classes to real life, thereby making abstract concepts concrete. Thus, they support classroom learning with experiential connections (Bozdoğan, 2008; Carrier, 2009; Henriksen & Frøyland, 2000). The cognitive, affective, and behavioral interactions offered by out-of-school learning environments provide various opportunities for science learning. In these environments, students develop science-related learning through contact with scientific experiences. Integrating these environments into science curricula creates awareness among students that school is not the only place for science learning (Fenichel & Schweingruber, 2010).

When linked to the objectives of the science curriculum, out-of-school learning environments such as zoos, aquariums, museums, and science centers have a positive impact on students' attitudes, knowledge, skills, and scientific literacy. The engaging and attention-grabbing nature of these environments increases students' interest and curiosity, contributing to a continuous and enjoyable learning process within the cultural and social context of science. The rich resources available in out-of-school learning environments deepen students' science learning and scientific literacy (Kim & Dopico, 2016). The increased interest and motivation provided by the fun structure of out-of-school learning environments enables students to increase their science knowledge. In addition to increasing their knowledge, students develop positive attitudes while acquiring social or motor skills related to science (Avraamidou, 2014; Sasson, 2014).

Numerous studies exist on the positive effects of extracurricular learning activities conducted as part of science courses on factors such as students' knowledge, skills, attitudes, and behaviors toward science courses. Jarvis and Pell (2005) stated that a visit to the National Space Center with students had a positive effect on their interest and attitudes towards science classes. Sturm and Bogner (2010) stated in their study that visits to science museums with students increased their academic achievement and motivation. Stavrova and Urhahne (2010) stated in their study that museum visits increased students' knowledge of energy and helped them develop positive attitudes. Scott and Matthews (2011) stated in their studies that visits to zoos contributed to students' permanent and meaningful learning.

Erten and Taşçı (2016) organized a trip to a hobby garden with students. The researchers noted that students who participated in the hobby garden trip used more scientific process skills. In his study, Bülbül (2018) stated that the trip organized to the Giresun Tirebolu Aslancık Hydroelectric Power Plant increased students' academic achievement in science lessons. Szczytko et al. (2018) stated in their studies that science education conducted outdoors increased academic achievement and developed positive behavior in students with learning difficulties. Demir & Öner Armağan (2018) stated in their study that the trip to the planetarium supported the retention of learning, increased interest in the course, and enabled the concretization of abstract concepts. Demirel and Özcan (2020) stated in their study that the trip to the tropical butterfly garden reinforced the students' learning in the classroom.

Yavuz Topaloğlu and Balçın (2021) stated in their study that nature education trips and science center visits positively affected students' attitudes toward science classes. Schmaing and Grotjohann (2023) took students on a mudflat walk in the Wadden Sea in their study. The researchers stated that this activity had a positive effect on students' attitudes towards the environment. In their study, Tayşi-Tafracı and Aydın (2024) investigated the effectiveness of out-of-school learning environments in science education using an experimental design. The researchers conducted activities in three different out-of-school learning environments with the experimental group: a hospital, a health authority, and a picnic area. The results of the study showed that the experimental group differed significantly in terms of academic achievement and attitudes towards the course.

Science education is an active field of science encompassing many disciplines. Science is not limited to pure knowledge of physics, chemistry, biology, astronomy, environmental education, and earth science. In addition to scientific knowledge about these disciplines, science education aims to foster positive attitudes toward the environment, equip individuals with various skills, cultivate scientifically literate individuals, and, in short, prepare individuals to live as well-equipped and productive members of society. Limiting science education, which is so closely intertwined with life, to the confines of school walls can have negative consequences on the effectiveness of the education provided. For effective science education, students need to be in contact with life, interact, create experiences, and experience things firsthand. In this context, the use of out-of-school learning environments to support science education is critical to achieving the goals of science education.

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ARTIFICIAL INTELLIGENCE AND SCIENCE EDUCATION

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INTRODUCTION

In recent years, interest in the role of artificial intelligence in education has been increasing (Holt & Wood, 1990). Developing artificial intelligence is rapidly influencing the fundamental nature of education (Popenici & Kerr, 2017). Students, teachers, and educational institutions are also contributing to this development, accelerating advancements in the field of artificial intelligence in education (Wang et al., 2024). Artificial intelligence is a discipline of computer science that focuses on understanding human thinking processes and reproducing the effects of these processes through information systems (Wang et al., 2024). Artificial intelligence aims to design systems capable of performing human-like cognitive abilities such as perception, reasoning, learning, and planning, and in this way modeling human behavior (Gil de Zuniga et al., 2024).

It has been determined that artificial intelligence applications are largely implemented in the field of science education and that artificial intelligence tools particularly natural language based applications such as ChatGPT are widely used; these tools have been found to influence learning outcomes related to the learning process, although researchers highlight ethical issues and limitations (Erumit & Ozdemir Sarıalioglu, 2025). A review of the literature shows that the integration of artificial intelligence into science education is still in its early stages and that widespread implementation has not yet emerged (Arici, 2024). Artificial intelligence applications have been shown to have the potential to contribute to students' online learning processes, facilitate learning, provide multiple (especially auditory) learning environments for science laboratories, support interdisciplinary learning experiences, and promote personalized learning (Erumit & Ozdemir Sarıalioglu, 2025).

In order to offer students higher-quality content and personalized services, optimize in-class educational processes, and support instructional plans so that teaching resources can be produced more effectively, it is essential to conduct comprehensive research on artificial intelligence algorithms, instructional paradigms, and effective AI applications. This necessity requires a holistic and in-depth examination of the field of artificial intelligence in education (Peng & Liu, 2025).

In this chapter, artificial intelligence in education, current studies related to AI in education, the findings of these studies, the controversial issues surrounding artificial intelligence in education, and recommendations in light of the literature will be addressed.

Literature Review

International Studies

It is known that the concept of artificial intelligence was first introduced approximately seventy years ago, and studies aimed at making this technology more functional and advanced have continued uninterrupted throughout this period. Today, the use of artificial intelligence in the field of education is becoming increasingly widespread and diversified. In this section, several recent international studies conducted on the subject are examined.

Cooper et al. (2025) found that pre-service teachers at the university level actively used artificial intelligence tools (especially those such as ChatGPT) in lesson planning, content summarization, and assessment preparation because these tools provide a more interactive user experience than traditional search engines. They determined that pre-service teachers who actively use artificial intelligence are aware of the pedagogical potential of these tools; however, they have not yet reached a sufficient level of awareness regarding issues such as ethics, data security, and bias generation. They stated that artificial intelligence tools support students' inquiry-based learning processes in applications such as exploring scientific concepts, conducting experimental simulations, and performing data analysis. They concluded that institutions should provide pedagogical training and continuous professional development opportunities for pre-service teachers to use artificial intelligence tools both effectively and ethically.

Garzon et al. (2025) conducted a review study and examined research conducted between 2015 and 2025. They identified a significant increase in the number of studies on artificial intelligence after the year 2022. In these studies, they found that artificial intelligence has benefits such as improving learning outcomes, offering personalized instructional opportunities, and increasing student motivation. However, they also stated that challenges such as the need for students to use artificial intelligence ethically, teachers' resistance toward artificial intelligence systems, and the potential digital addiction that may arise from these systems must be overcome. The research revealed the potential of artificial intelligence to improve education; however, realizing this potential depends on a careful implementation process and collaboration among educators, researchers, and policymakers.

Kunnath and Botes (2025), in their study aiming to investigate the effects of integrating artificial intelligence technologies into science education—particularly on inquiry-based learning and scientific reasoning skills—reported that artificial intelligence tools provide guidance in students' scientific investigation processes and offer effective learning experiences especially in data analysis, problem identification, and solution generation. They observed significant improvements in students' higher-order cognitive skills such as making observations, drawing inferences, and producing evidence-based explanations in artificial intelligence–supported environments. They noted that artificial intelligence systems that can adapt to students' knowledge levels personalize the learning process by providing content suited to different learning paces, thus promoting more effective and lasting learning. Although teachers indicated that artificial intelligence is a supportive tool in classroom practices, they emphasized that teachers still play a central role in pedagogical decision-making processes. They identified technical competence, teacher training, access inequalities, and ethical concerns as major limiting factors in the integration of artificial intelligence applications into the classroom environment.

Oh and Lee (2025), in their study in which they conducted interviews with ChatGPT and analyzed its responses to questions about the future epistemic position of humans in science education, aimed to reveal the ontological and relational consequences between humans and artificial intelligence. They stated that scientific knowledge produced by humans still possesses distinctive characteristics compared to knowledge generated by artificial intelligence. As a result, they proposed that artificial intelligence should be understood as a collaborator in knowledge construction in science education; however, the leadership of human learners must be safeguarded in this process.

Alshorman (2024) examined the extent to which science teachers are prepared for the integration of artificial intelligence into science education, their perceptions of this technology, the challenges they encounter, and the training they need. The findings revealed that teachers' preparedness levels for artificial intelligence integration vary depending on gender, academic background, and concerns regarding data security and privacy. Although teachers generally approach the opportunities offered by artificial intelligence in education positively, limited access to technology and insufficient professional development opportunities emerge as significant barriers. The results indicate that developing specific policies and offering comprehensive training programs are essential for better preparing teachers to use artificial intelligence.

In the study conducted by Arantes (2024), it was revealed that artificial intelligence reproduces existing cultural and social biases rather than reflecting scientific reality. The representation of the expression "physicist" in text-to-image models primarily through male and Western figures deepens the historical representation problems in science education. Similarly, stereotypical narratives in text generation processes—such as assuming a physics teacher to be male and an art teacher to be female—were identified as indicators of algorithmic gender bias. The fact that even teacher roles are shaped according to these biases was interpreted as evidence that scientific fields are systematically associated with masculinity. In addition, the tendency of artificial intelligence to generate hallucinations weakens epistemic trust in science education and increases the necessity for pre-service teachers to critically evaluate the accuracy of generated information. Employing the "technical agonism" approach, the study concluded that accuracy is not a singular and fixed concept and that teachers must develop epistemic flexibility to cope with multiple truths and knowledge conflicts.

Ayeni (2024) examined how artificial intelligence technologies can be used in science education. The study concluded that artificial intelligence can adapt instructional content according to students' individual learning styles, analyze their strengths and weaknesses to offer tailored interventions, and provide opportunities for students to explore scientific concepts by conducting experiments outside the classroom through tools such as virtual laboratories and simulations. Artificial intelligence–based analysis tools support teachers in improving curriculum and instructional strategies by analyzing student performance and interaction levels. Tools such as text-to-speech and real-time translation facilitate access to education for students from different languages and those with special needs. Intelligent tutoring systems and chatbots reduce teachers' workload while providing students with instant feedback. The study found that artificial intelligence–supported learning environments improve students' critical thinking, problem-solving, and understanding of scientific methods.

Li and Ironsi (2024) examined the effects of pre-service teachers' epistemological beliefs, inquiry-based thinking approaches, and learning strategies during a science education process in which they interacted with artificial intelligence–based chatbots (particularly ChatGPT). They concluded that the science education process involving interactive engagement with ChatGPT enriched pre-service teachers' epistemological approaches to knowledge, encouraged critical and inquiry-based thinking, and contributed to more active management of learning processes. However, for this process to be effective, pre-service teachers must develop the ability to use artificial intelligence tools consciously, critically, and with pedagogical sensitivity.

Antonenko and Abramowitz (2023), in their study with K–12 science teachers, aimed to determine their understanding of artificial intelligence, their intentions to integrate it into the classroom, and their perceptions of artificial intelligence. The study concluded that K–12 science teachers are both excited and vulnerable in terms of knowledge about artificial intelligence and that their willingness to bring artificial intelligence into the classroom is strong; however, if this willingness is not supported by proper understanding, the potential of artificial intelligence in education may not be realized.

Cooper (2023) examined the effects of students' dialogues with ChatGPT on their scientific reasoning, cognitive engagement, inquiry-based thinking, and learning motivation. The study concluded that artificial intelligence tools such as ChatGPT can be effective digital learning partners that deepen students' science learning, stimulate cognitive processes, and increase learning motivation. However, the effective use of these technologies requires the development of supportive components such as critical digital literacy, teacher guidance, and ethical awareness.

Studies Conducted in Turkey

A review of the literature shows that studies on artificial intelligence in the context of science education in Turkey have not yet reached the level necessary to meet expectations. In this section, several studies conducted in Turkey on artificial intelligence in science education are examined.

Acemioglu (2025), in a study examining the literacy levels of pre-service science teachers, concluded that pre-service teachers' conceptual knowledge was weak, pedagogical practices were limited, ethical awareness was at a moderate level, but this awareness did not translate into behavior.

Bizim et al. (2025) examined how a university faculty member used artificial intelligence tools in science education and their perceptions of this process. The study concluded that artificial intelligence tools can enrich instructional materials in science education and support learning processes; however, these tools may create an impression of the absoluteness of knowledge, which may weaken students' critical thinking skills. It was found that for effective instruction with artificial intelligence tools, teachers need ethical awareness, a critical pedagogical perspective, and technological competence, and that teachers should position artificial intelligence not merely as a producer of information, but as a partner that facilitates learning.

Efe and Efe (2025) examined teachers' perceptions of artificial intelligence in four dimensions: challenges encountered in artificial intelligence integration, readiness for artificial intelligence, learning-enhancing effects in artificial intelligence–supported learning, and artificial intelligence–supported assessment and feedback processes. The study found that the greatest barriers to artificial intelligence integration were insufficient training, concerns about data privacy, and lack of access to tools. This situation was interpreted as reflecting structural and institutional deficiencies in teachers' access to technology. It was found that familiarity with artificial intelligence significantly influenced teachers' readiness for artificial intelligence and their perceptions regarding AI-supported assessment. Additionally, teaching experience emerged as an important factor in the perception of barriers to artificial intelligence integration. The variable that most strongly predicted the perceived effect of artificial intelligence on student learning was teachers' perceptions of the potential benefits of artificial intelligence. Readiness for artificial intelligence was also found to be a significant predictor; however, the effect of perceived barriers was not significant.

Erumit and Ozdemir Sarıalioglu (2025) conducted a comprehensive systematic review of the use of artificial intelligence applications in science and chemistry education between 2014 and 2024 and the effects of these applications. According to the review findings, there was a significant increase in academic studies on the topic especially between 2021 and 2024. It was found that artificial intelligence–based applications were largely used in the context of science education and that ChatGPT and chatbots were frequently preferred in this process. These tools produced noteworthy effects particularly on learning-related outcomes; however, researchers also highlighted ethical risks and limitations associated with the use of these technologies in education. The findings indicated that these applications supported students' online learning, enhanced the overall learning experience, enable multimodal environments in science and chemistry laboratory courses, fostered interdisciplinary learning opportunities, and facilitated personalized learning.

Geldi and Orhan (2025), in their study, examined how artificial intelligence applications contribute to creativity and innovation skills in science education and revealed the advantages and limitations of this contribution. They concluded that artificial intelligence is a tool that strengthens creative processes, enables innovative pedagogies, and personalizes learning. However, they emphasized that critical thinking, original production, and ethical awareness are still human-centered.

Torun and Karamustafaoglu (2025), in a study in which they gathered students' opinions in the science course, concluded that the use of ChatGPT was generally received positively by students; that features such as visualization, instant feedback, and storytelling facilitated learning; and that the tool created a strong perception that it could also be effectively used in other courses, especially English and Mathematics.

Zorlu (2025) examined the effect of artificial intelligence–supported question generation on the development of critical thinking, social intelligence, and 21st-century skills in pre-service science teachers. The study concluded that artificial intelligence–supported question generation contributed to the development of pre-service teachers' 21st-century skills, social intelligence, and critical thinking tendencies. It was found that the improvements in 21st-century skills, social intelligence, and critical thinking resulted from communication-based interaction with artificial intelligence during the question-generation process, collaboration established through group work, and access to up-to-date information through technology.

Yilmaz (2024), in a study examining artificial intelligence and creativity applications, stated that artificial intelligence–based and transhumanism-oriented applications can identify students' individual learning needs and personalize learning materials, thereby enhancing students' learning experiences. He stated that artificial intelligence can process large amounts of data quickly to monitor and analyze student performance. This was interpreted as providing faster and higher-quality feedback to students and improving the learning process. He noted that simulations, visualizations, and creativity applications, when used interactively to better understand science topics, can help students comprehend scientific concepts more effectively by concretizing abstract concepts. However, he also stated that these applications can lead to negative situations such as technology addiction. He emphasized that the overutilization of artificial intelligence and creative technologies in science education may lead to an overreliance on digital tools among students and a neglect of conventional learning strategies; that deficiencies in technological infrastructure could obstruct the efficient implementation of these tools and interrupt the institutional support for teachers, the full pedagogical benefits of such technologies are unlikely to be realized.

Colak Yazici and Erkoc (2023), in their study examining the views of science teachers regarding what artificial intelligence is, found that teachers' awareness of artificial intelligence was limited; that artificial intelligence was perceived as a positive tool in education; that there were knowledge gaps in terms of application; that teachers had difficulty distinguishing artificial intelligence–supported applications from other educational technologies; and that demographic characteristics affected artificial intelligence use. They found that as education level and professional experience increased, usage rates also increased. The study concluded that unless systematic and applied artificial intelligence training is provided to teachers, the correct and effective use of artificial intelligence will remain limited.

Cam et al. (2021), in their study examining the awareness of pre-service science teachers and pre-service computer and instructional technology teachers regarding artificial intelligence technologies, found that pre-service teachers generally had a positive and high level of awareness regarding artificial intelligence. They stated that pre-service teachers viewed artificial intelligence as a supportive tool that does not replace the teacher but reduces the teacher's workload, enriches instruction, and provides a more personalized learning experience for students. The study concluded that artificial intelligence literacy should be strengthened in teacher education programs and that particularly the "learning" dimension of artificial intelligence, its ethical aspects, its role in assessment processes, and its pedagogical uses should be taught to pre-service teachers in a more systematic manner.

Advantages of Using Artificial Intelligence in Education

Studies show that artificial intelligence–supported learning environments significantly improve learning outcomes by offering interactive and personalized learning experiences that are responsive to students' individual needs. Artificial intelligence technologies contribute to the development of high-level cognitive skills, particularly in disciplines such as science and mathematics, by supporting the exploration of scientific concepts, experimental simulations, data analysis, and problem-solving. In these environments, students take an active role in processes such as making observations, drawing inferences, and producing evidence-based explanations; this strengthens their critical thinking and scientific reasoning skills. In addition, the ability of artificial intelligence systems to adapt content according to students' knowledge level and learning pace personalizes instruction and increases learning motivation.

The real-time feedback mechanisms offered by artificial intelligence–based tools make it possible to identify students' strengths and areas for improvement and to make instant interventions in the learning process. These tools also provide significant support for teachers in monitoring student performance and shaping instructional strategies accordingly. Simulations, visualizations, and storytelling techniques facilitate the concretization of abstract concepts, thereby increasing depth of learning, particularly in science instruction.

Important contributions of artificial intelligence are also observed in the domain of teacher education. It has been found to diversify pre-service teachers' epistemological approaches toward knowledge, encourage inquiry-based and critical thinking tendencies, and help them manage instructional processes more effectively. In addition, applications such as artificial intelligence–supported question generation have been found to be effective in developing pre-service teachers' 21st-century skills and social intelligence. Furthermore, it is emphasized that teachers develop a positive attitude toward artificial intelligence technologies.

The integration of artificial intelligence tools into education has emerged as a catalyst that reshapes learning experiences, encourages innovation, and prepares individuals for the digital age (Abulibdeh et al., 2024). In science and chemistry education, artificial intelligence applications have been found to be effective particularly on learning-related outcomes; they contribute to online learning, facilitate learning, support the structuring of knowledge, provide multimodal learning environments in laboratory courses, promote interdisciplinary and personalized learning, and enhance equity in learning environments (Erumit & Ozdemir Sarıalioğlu, 2025). Based on this, the integration of artificial intelligence into science education not only enriches instructional methods but also increases students' levels of scientific understanding and supports teachers' pedagogical effectiveness (Ayeni, 2024).

Risks and Challenges in the Use of Artificial Intelligence in Education

While artificial intelligence technologies offer significant opportunities in education, their integration into pedagogical processes brings various challenges and risks. Studies in the literature reveal that although teachers and pre-service teachers are aware of the potential of artificial intelligence tools, they lack sufficient awareness in areas such as ethics, data security, digital addiction, and the generation of bias. The integration of artificial intelligence applications into classroom environments is limited by structural problems such as deficiencies in technical infrastructure, inequalities in access, and insufficient professional development opportunities for teachers. In addition, teachers' continued central role in pedagogical decision-making processes may trigger professional resistance to the integration of artificial intelligence into instructional strategies.

The fact that information generated by artificial intelligence possesses characteristics that distinguish it from human-produced scientific knowledge creates the risk that teachers and students may perceive such content as absolute truth. This may weaken critical thinking skills. Furthermore, excessive use of artificial intelligence and creativity applications may lead students to distance themselves from traditional learning methods and develop dependence on technology.

Artificial intelligence applications in education also bring ethical and societal issues; especially excessive trust in artificial intelligence carries the risk of weakening students' critical thinking and fundamental academic skills, and teachers' capacities for personalized instructional planning and deep reflection. Moreover, the use of artificial intelligence may facilitate academic misconduct and plagiarism, while hallucination generation and biased outputs decrease its reliability. In this context, it is necessary to enhance the transparency and interpretability of artificial intelligence decisions (Peng & Liu, 2025).

According to Geldi and Orhan (2025), the emotional and intuitive dimensions of human creativity cannot be fully replicated by artificial intelligence—that is, artificial intelligence supports creative thinking but cannot fully replace students' original and independent production. Excessive dependence on artificial intelligence may weaken creative confidence and lead to violations of privacy, data security, and academic integrity. In contrast, according to Chatzichristofis (2025), completely rejecting artificial intelligence may hinder students' critical and creative interaction with systems that shape their future, close opportunities for pedagogical transformation, and deprive them of the chance to participate as ethical co-interpretive agents in the learning process—in fact, interpretive capacity is highly important for the democratic vision of education.

Conclusion and Summary

Effective, ethical, and sustainable use of artificial intelligence technologies in education depends not only on technical infrastructure but also on multifaceted preparation at pedagogical, ethical, and policy levels. Studies indicate that leveraging the potential of artificial intelligence in education requires a holistic and careful collaboration process among teachers, researchers, and policymakers.

To enable pre-service teachers to use artificial intelligence tools consciously, critically, and with pedagogical sensitivity, systematic and practice-based artificial intelligence literacy training must be strengthened within teacher education programs. In this context, it is important to integrate not only technological skills but also human-centered qualities such as ethical awareness, critical thinking, epistemic flexibility, and original production into educational processes. Teachers need to position artificial intelligence not merely as a tool that produces information, but as a digital partner that facilitates the learning process. Educators, by using artificial intelligence tools directly in ways that align with data privacy and ethical principles, initiate processes of discussion, reflection, and creative expression, thereby both maintaining control over instruction and supporting culturally enriched, multidimensional meaning-making (Chatzichristofis, 2025).

The successful use of artificial intelligence applications in education depends on teachers' ability to integrate technology with pedagogical goals and their access to supportive professional development opportunities. When teachers are not provided with the necessary training and support to use these tools effectively, the potential offered by artificial intelligence will remain limited, and the sustainability of applications cannot be ensured. Therefore, increasing teachers' levels of critical digital literacy and structuring educational policies accordingly is of great importance. Teacher education programs must adopt an interdisciplinary structure with in-depth conceptual content, practice- and scenario-based learning opportunities, and ethical decision-making processes to strengthen artificial intelligence literacy (Acemioglu, 2025). How artificial intelligence will be integrated into the classroom depends entirely on the ethical and interpretive frameworks surrounding it; these frameworks are guided by educators and emphasize human meaning-making (Chatzichchristofis, 2025).

It is predicted that the applications of artificial intelligence in education will become increasingly widespread, depending on the growing willingness of teachers and students. A review of national and international literature indicates that significant gaps exist in this field, particularly regarding practice-oriented studies. Increasing the number of applied studies on artificial intelligence, especially in the context of science education, will make meaningful contributions to the literature.

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WHAT DOES SCIENCE TEACH IN PRIMARY SCHOOL, AND HOW DOES IT TEACH? AN EVALUATION OF THE CURRICULUM THROUGH THE TÜRKIYE CENTURY MAARIF MODEL

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Rethinking the Question: What Does Primary School Science Teach, and How?

Primary school science education is a fundamental learning domain that shapes not only children's acquisition of "knowledge," but also their ways of explaining the world, thinking with evidence, approaching everyday problems from a scientific perspective, and understanding the relationship between science and society. This perspective is closely aligned with international frameworks that define scientific literacy through competencies such as explaining phenomena scientifically, evaluating and designing scientific inquiry, and drawing inferences based on data and evidence (Organisation for Economic Co-operation and Development [OECD], 2019a).

The Science Curriculum renewed within the framework of the Türkiye Century Maarif Model (TCMM) presents a program philosophy that does not confine science teaching at the primary level to the narrow scope of "content or concept instruction." Instead, it adopts a holistic architecture that integrates subject-specific skills, conceptual skills, dispositions, social-emotional skills, values, and various literacies. The curriculum document explicitly states that the Turkish education system is grounded in a "holistic education approach," aiming to support students' multidimensional development—cognitive, social, and affective—simultaneously (Ministry of National Education [MoNE], 2024). This emphasis is consistent with contemporary science education research, which broadly recognizes that students' scientific reasoning and problem-solving performance is related not only to conceptual knowledge but also to psychosocial components that sustain learning, such as self-regulation, collaboration, and motivation (Collaborative for Academic, Social, and Emotional Learning [CASEL], 2020). An examination of the "what does it teach?" dimension of the curriculum reveals that its objectives are defined across a much broader axis than the mere transmission of scientific knowledge. The explicit aims of the program include educating individuals who possess the skills required by the contemporary world and a disposition toward lifelong learning; who can employ higher-order thinking and scientific process skills; who embrace ethical and moral values; and who are inquisitive, questioning, critical thinkers with environmental awareness (MoNE, 2024). This orientation is also consistent with international science education frameworks that advocate placing "scientific practices"—such as asking questions, modeling, planning investigations, analyzing data, and engaging in evidence-based argumentation—at the center of learning (National Research Council [NRC], 2012).

With regard to the "how does it teach?" dimension, the curriculum points to a learning design that prioritizes students' active participation in the learning process, collaboration, self-regulation, and skill development (MoNE, 2024). A distinctive emphasis of the curriculum is also evident in its assessment and evaluation approach. The program highlights the integration of assessment tools into the instructional process based on feedback; the prioritization of process-oriented assessment; students' active involvement in the assessment process; and the provision of feedback at every stage of learning (MoNE, 2024). This approach aligns with extensive review evidence demonstrating that formative assessment strengthens learning (Black & Wiliam, 1998). Furthermore, the program's emphasis on performance-based assessment tools and analytic scoring rubrics can be interpreted as a reflection of contemporary assessment approaches aimed at evaluating skill-based competencies in a more objective and traceable manner.

Within the new science curriculum, social-emotional learning skills, literacies—particularly sustainability and digital literacy—and values are presented under the heading of "cross-curricular components" and are linked with subject-specific skills in an integrated structure (MoNE, 2024). This integration parallels UNESCO's Education for Sustainable Development (ESD) for 2030 agenda, which emphasizes that education should support sustainable living practices and responsible citizenship in alignment with the United Nations' sustainable development agenda (UNESCO, 2020). At this point, a comparative reading is necessary in order to discuss the renewed structure of the curriculum from a scholarly perspective. While the 2018 Science Curriculum also placed the goal of educating "scientifically literate individuals" at its core (MoNE, 2018), developments since the 2014 science curriculum are notable in terms of the program's language and architecture—particularly the more systematic treatment of holistic components (social-emotional skills, values, and literacies) and the clearer emphasis on feedback- and process-oriented assessment.

In this chapter, the Science Curriculum renewed within the framework of the Türkiye Century Maarif Model is examined with a specific focus on the primary school level, and the program's pedagogical approach, content structure, and principles of implementation are evaluated from a holistic perspective. Throughout the analysis, the underlying philosophy of the curriculum, its core principles, and the new meanings attributed to science teaching are discussed in detail. A comparative reading with the 2018 Science Curriculum is conducted to identify areas of continuity and transformation. Within this framework, cross-curricular components, the content framework, learning–

teaching experiences, assessment and evaluation approaches, and differentiation practices are addressed in light of current educational research and international approaches to science education. Ultimately, the chapter aims to examine how science teaching moves beyond knowledge transmission to integrate skills, values, literacies, and social-emotional learning, and to elucidate how the scientific thinking and life skills required by the contemporary era are structured at the primary school level.

The Türkiye Century Maarif Model's Approach to Science Teaching

Program philosophy: a science education perspective centered on holistic development

The Science Curriculum developed on the basis of the Türkiye Century Maarif Model (TCMM) is built upon a holistic educational approach that prioritizes the comprehensive development of the individual, which constitutes a fundamental pillar of the Turkish education system. The philosophy of the curriculum aims not only to equip students with academic knowledge but also to support their development as a whole across cognitive, affective, social, and ethical dimensions. In this context, subject-specific skills and conceptual skills, together with dispositions, social-emotional skills, values, and literacies, are not treated as independent learning domains; rather, they are conceptualized as interrelated components that interact with one another to form a cumulative and holistic developmental process (MoNE, 2024). This approach also aligns with international education indicators. In the OECD Learning Compass report, the core goals of 21st-century education are defined within a framework that emphasizes individuals' well-being, learner autonomy/agency, and the integrated development of cognitive, social, and emotional skills (OECD, 2019b).

This holistic perspective was also articulated in the 2018 Science Curriculum through the emphasis on educating "individuals who possess knowledge, skills, and behaviors integrated with our values," with values positioned as a guiding framework that directs the learning process and serves a "horizon function" (MoNE, 2018). In the 2024 curriculum, while this foundational approach is preserved, holistic competencies—such as self-regulation, collaboration, critical thinking, and problem solving—are placed more directly, more visibly, and more systematically at the center of science teaching. From this perspective, the curriculum conceptualizes learning not merely as a process of acquiring knowledge, but as a dynamic process that fosters students' abilities to engage in scientific reasoning, make evidence-based decisions, and evaluate these decisions within social and ethical contexts.This process is structured around four core developmental domains defined in the curriculum; these domains are designed to form a holistic pattern that is mutually reinforcing, progresses through continuous interaction, and gradually deepens students' development over time (MoNE, 2024).

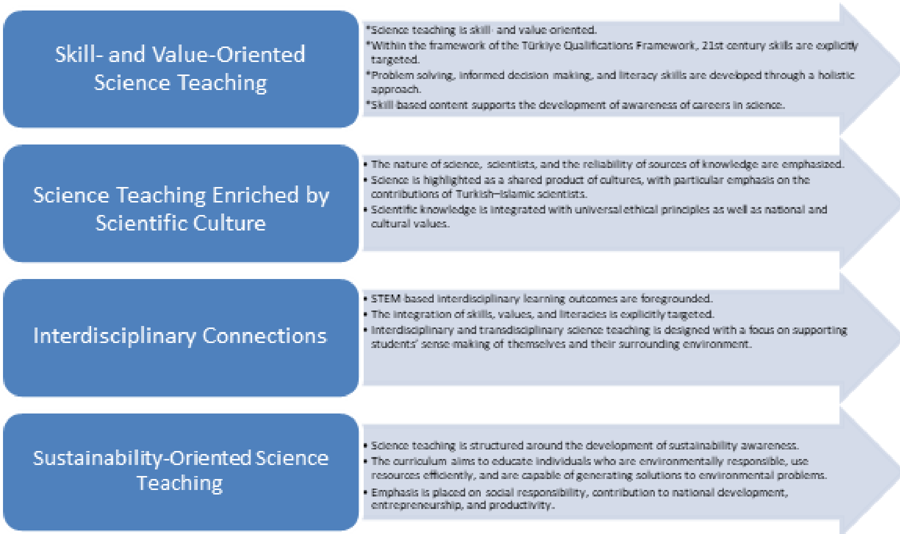

Figure 1. *Developmental Domains of the Science Curriculum (MoNE, 2024)*

Explanatory Note: Adapted on the basis of the developmental domains included in the 2024 Science Curriculum.

Core principles: "what kind of science teaching?" through principles of implementation

The Science Curriculum of the Türkiye Century Maarif Model (TCMM) (2024) provides its clearest answer to the question "What kind of science teaching?" through its principles of implementation. The curriculum explicitly states that it is structured around the Common Framework Text, and that lesson design, assessment planning, and material development processes should be carried out in alignment with this framework. This emphasis positions science teaching not merely as a "list of learning outcomes," but as a design logic oriented toward achieving the targeted student profile. Although the 2018 curriculum also expected teachers to adapt instruction based on "holistic human development" and "individual differences" (MoNE, 2018), the new curriculum articulates this approach in a more operational manner by embedding it within the design–implementation–assessment triangle, thereby making it the backbone of practice (MoNE, 2024). This orientation can be seen as aligned with international large-scale assessments, particularly the PISA framework, which conceptualizes scientific literacy not as the reproduction of knowledge, but as evidence-based reasoning, decision making, and problem solving in real-life contexts (OECD, 2023a; OECD, 2023b).

A second strong dimension of the implementation principles relates to equity and continuity. In grades where the curriculum is introduced progressively, schools are expected to identify prior learning gaps from lower levels through subject-area teams and to integrate these into annual instructional plans (MoNE, 2024). This approach moves teaching away from the "same content–same pace" template and systematically defines the responsibility of managing students' readiness levels. International indicators—including PISA result reports and the OECD's equity-focused analyses—place issues such as opportunity gaps, learning loss, and remediation mechanisms at the center of educational discussions alongside achievement. In this respect, the 2024 curriculum's emphasis on remediation and gradual transition is consistent with global trends (OECD, 2023a; OECD, 2024).

A third response to the question "What kind of science teaching?" becomes evident in the quality of learning–teaching experiences. The curriculum describes learning experiences as a comprehensive framework that fosters a holistic perspective, supports durable learning, mobilizes diverse methods and techniques, and makes interdisciplinary connections visible. At the same time, while process components are regarded as essential, the curriculum emphasizes that differentiation can be implemented—even in recommended practices—by taking learning outcomes and cross-curricular components into account (MoNE, 2024). This approach is consistent with contemporary science education frameworks that foreground scientific practices, interdisciplinary thinking, and real-world contexts (National Research Council [NRC], 2012). Moreover, the curriculum's emphasis on classroom climate—active participation, the free expression of ideas, and the support of social-emotional skills—positions science learning not merely as a cognitive process, but as an experience that develops within a learning community (MoNE, 2024). Indeed, meta-analytic evidence demonstrating that school-based social-emotional learning interventions yield significant gains in both social-emotional outcomes and academic achievement supports the view that classroom climate and the integration of Social and Emotional Learning are not "add-ons," but core components of effective instruction (Durlak et al., 2011).

One of the most critical aspects of the curriculum's core principles emerges in assessment and evaluation, where science teaching is clearly distinguished from a "results-oriented examination" logic. The 2024 curriculum prioritizes performance-based assessment tools in skill-oriented evaluation, emphasizes students' active participation in the assessment process, and highlights the use of rubrics (analytic scoring tools) to ensure the objective assessment of skills. Assessment practices are explicitly framed as formative, with the primary aim of supporting instruction and learning (MoNE, 2024). Research shows that classroom-based assessment and feedback cycles significantly enhance learning (Black & Wiliam, 1998), and that the impact of feedback on learning can be particularly powerful depending on its quality (Hattie & Timperley, 2007). While the 2018 curriculum emphasized "maximum diversity and flexibility" in assessment—stating that standardized assessment was inappropriate and that teachers were expected to demonstrate originality within broadly defined boundaries (MoNE, 2018)—the 2024 curriculum advances this principle further by explicitly anchoring assessment in a feedback-based, process-integrated, and rubric-structured architecture (MoNE, 2024). Thus, the key distinction in 2024 becomes evident not only in "what is assessed," but in "what assessment is for."

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In summary, the science teaching model derived from the implementation principles of the 2024 curriculum appears to require the integrated consideration of the following components:

- design centered on the common framework text and the targeted student profile;
- an equity focus supported by gradual transition and the management of prior learning;
- enriched learning experiences through interdisciplinary integration and methodological diversity;
- a learning community attentive to classroom climate and social-emotional development;
- rubric-based, performance-oriented, and feedback-driven assessment practices.

International assessments and reports further reinforce an orientation toward evidence, reasoning, and real-life problem solving in scientific literacy. While the TIMSS framework monitors scientific knowledge and reasoning at the primary level alongside content domains (IEA, 2020), PISA reports address learning in conjunction with equity considerations (OECD, 2023a). From this perspective, compared to the 2018 curriculum, the 2024 curriculum preserves the legacy of holistic development and flexibility, while redefining science teaching more explicitly along an implementation axis in which skills, values, and literacies are embedded within lesson design and assessment systematics.

The implementation logic of the Türkiye Century Maarif Model Science Curriculum: a five-component teaching ecosystem

The principles guiding the implementation of the Türkiye Century Maarif Model (TCMM) Science Curriculum conceptualize science teaching not as a linear process of “content transmission,” but as a holistic, skill-based, and process-oriented teaching ecosystem (MoNE, 2024). Rather than prescribing what teachers should do step by step, the curriculum is structured around five core components that illustrate how an instructional design should be constructed. Within this framework, science teaching is built upon an instructional approach that places cross-curricular components at its center, views content as interwoven with skills, monitors learning through evidence, designs learning–teaching experiences around inquiry and design, and defines differentiation as a professional responsibility of the teacher (MoNE, 2024).

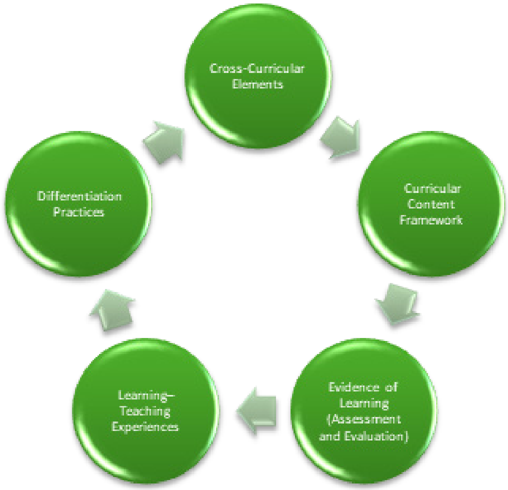

Figure 2. *Implementation Components of the Türkiye Century Maarif Model Science Curriculum*

Cross-curricular components are addressed along the axes of social-emotional learning (SEL) skills, literacy skills, and values (MoNE, 2024). When examined within this framework, social-emotional learning skills, literacies, and values are not viewed as complementary add-ons to science teaching; rather, they are conceptualized as integrative components that determine the quality of learning itself. Social-emotional learning skills are defined as a structure that enables students to establish healthy relationships with themselves and their environment, while simultaneously mediating the effective use of conceptual and subject-specific skills (MoNE, 2024). Indeed, research indicates that school-based SEL programs enhance social-emotional competencies, reduce behavioral problems, and increase student engagement and academic performance (Greenberg, 2023; Kaufmann, 2020).

Literacy skills are integrated with science subject-specific skills to support students' ability to relate scientific knowledge to everyday life, make responsible decisions, and participate actively in social life. In this regard, the curriculum focuses on developing competencies required by the contemporary era, such as information and sustainability literacy, as well as digital and financial literacy (MoNE, 2024). The values dimension situates science teaching within an ethical, environmental, and cultural context, aiming to ensure that knowledge acquires a quality that goes beyond cognition and is transformed into attitudes and behaviors (MoNE, 2024). Interdisciplinary and value-oriented approaches, in turn, can be said to help students render scientific topics more meaningful by relating them to social contexts (Hill, 2024).

From the perspective of the content framework, the Science Curriculum (MoNE, 2024) clearly demonstrates that content is no longer conceived merely as a "list of topics," but rather as a skill-based and integrated learning system. Guiding students toward collecting, analyzing, and interpreting data, as well as making evidence-based generalizations, indicates that critical thinking and

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problem solving are directly embedded within content. Emphases on laboratory safety, model construction, the use of digital content, and the engineering design cycle aim to structure learning in an experiential and safe manner. The recommendation of models, animations, and simulations for unobservable concepts renders teachers' pedagogical preparation and digital competence integral parts of content implementation. Furthermore, references to the history of science, Atatürk's emphasis on science, and Turkish–Islamic scientists situate science content within ethical, cultural, and historical contexts, thereby strengthening the understanding of science as a universal yet inherently social human endeavor. Supported by interdisciplinary connections, links to everyday life, and contemporary themes such as sustainability, this structure demonstrates that content is presented within a coherent pedagogical framework aligned with the principles of "from near to far" and "from concrete to abstract" (MoNE, 2024).

Evidence of Learning emerges as a component that explicates the process-oriented and formative assessment approach adopted in the Science Curriculum. Within this scope, assessment is positioned not as a tool that marks the end of learning, but as a process that guides learning itself (MoNE, 2024). The emphasis on performance-based assessment tools, the use of rubrics, students' active participation in the process through self- and peer assessment, and continuous feedback aligns with research demonstrating the strong impact of formative assessment on learning. Numerous synthesis studies have shown that classroom-based formative assessment significantly enhances students' conceptual understanding and academic achievement, and that feedback plays a critical role in the learning process (Black & Wiliam, 1998; Hattie & Timperley, 2007). Moreover, targeting higher-order thinking skills (reasoning, analysis, interpretation) and relating assessment tasks to real-life problems is consistent with contemporary assessment approaches aimed at fostering scientific literacy (Shavelson et al., 2008). In this respect, while the program maintains the flexible and multiple-assessment orientation of the 2018 Science Curriculum, it frames assessment and evaluation within a more systematic, feedback-based, and learning-integrated structure.

When considered through the lens of learning–teaching experiences, the Science Curriculum conceptualizes instruction not as a set of activities that transmit knowledge, but as a learning process built upon students' prior knowledge and grounded in inquiry and sense-making. The emphasis on "core assumptions," diagnostic assessment, and "bridging" between learnings reflects a constructivist view of learning and aims to foster durable learning by highlighting the determining role of prior knowledge in connecting new information to existing cognitive schemas (Bransford et al., 2000). The explicit emphasis on interdisciplinary relationships and connections among skills in learning–teaching practices moves science learning beyond single-discipline knowledge transmission and provides a structure that supports higher-order thinking and transfer skills. Defining students as active learners who take responsibility, possess self-regulation skills, and demonstrate scientific attitudes—while positioning teachers as guides who provide cues and feedback—

aligns with inquiry-based and research-oriented instructional approaches (Hmelo-Silver et al., 2007).

In line with a skill-based orientation, the inclusion of problem-based, project-based, research–investigation, and engineering design–based strategies transforms science teaching into a process in which students produce knowledge through its application. The science education literature robustly reports that such learning environments strengthen students' scientific process skills, motivation, and conceptual understanding (National Research Council, 2012). In addition, the integration of out-of-school learning environments (e.g., museums, science centers, planetariums) into learning–teaching experiences is regarded as an effective means of supporting the interpretation of knowledge within real-life contexts (MoNE, 2024).

One of the most prominent components of the curriculum is differentiation. In the Science Curriculum (MoNE, 2024), differentiation is structured as the enrichment or support of learning experiences across content, process, and product dimensions without removing students from shared learning environments. By incorporating digital content and independent learning environments that take into account students' individual learning paces and readiness levels, the program transforms differentiation from a flexibility left to teacher discretion into a planned and systematic pedagogical principle. In this respect, the new curriculum places differentiation at the very center of the instructional process. While differentiation in the 2018 Science Curriculum was addressed primarily through general adaptations and activity variety under teacher guidance, within the Türkiye Century Maarif Model (TCMM) differentiation has acquired a structure aimed at deepening learning through interdisciplinary and transdisciplinary activities, digital production processes, and performance-based tasks. This approach is consistent with contemporary theoretical frameworks that emphasize differentiation not only as a means of support, but also as a mechanism for enrichment and the promotion of advanced learning (Tomlinson, 2014).

What has changed, what has remained? unit-level innovations in the 2024 primary school science curriculum: a pedagogical reading

When compared with the 2018 Science Curriculum, the 2024 Science Curriculum represents a clear shift in primary school science teaching—from a structure centered on content density toward a pedagogical approach that places students' sense-making processes at the core. This transformation is particularly evident in unit structures, the number of learning outcomes, and unit titles. Whereas the previous curriculum included 36 learning outcomes at Grade 3 and more than 40 at Grade 4, the 2024 curriculum replaces this structure with a more limited number of learning outcomes that are cognitively more focused. The specification of 20 learning outcomes in Grade 3 and 19 in Grade 4 can be interpreted not merely as quantitative simplification, but as a strategy aimed at pedagogical deepening. Indeed, an examination of the outcomes shows that each is elaborated through sub-outcomes, indicating an intentional move toward depth rather than breadth. International literature

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likewise emphasizes that excessive content load—especially at early ages—tends to result in superficial learning, whereas a smaller number of well-structured and meaningful goals strengthens conceptual understanding (Hattie, 2009; Kirschner et al., 2006). Nevertheless, the assumption that reducing the number of learning outcomes will automatically lead to deeper learning remains pedagogically debatable. What ultimately proves decisive is the quality of the learning outcomes, how they are addressed in instruction, and how they are connected to assessment processes. At this point, it can be argued that the curriculum (MoNE, 2024) should provide a clearer rationale; otherwise, simplification risks turning into mere "content reduction" in practice.

The transformation described above is reflected not only in the number of learning outcomes, but also in unit titles and overall unit design. While the 2018 curriculum predominantly employed concept-centered titles such as "Let's Get to Know Our Planet," "Let's Get to Know Matter," and "Let's Get to Know Force," the 2024 curriculum foregrounds action- and experience-oriented titles that position students as active agents in the learning process, such as "A Scientific Discovery Journey," "Earth Scientists at Work," and "Energy Detectives." This shift suggests that science teaching has been reconfigured away from the question "What are we teaching?" toward "How does the student experience this knowledge?"—a move that reflects the curriculum's stated emphasis on real-life, context-based learning. However, process-oriented unit titles alone do not automatically guarantee that classroom practices will be inquiry-based, experiential, or contextualized. Research indicates that inquiry-based instruction is closely related to teachers' pedagogical competence, material support, and classroom management skills (Bennett et al., 2007; Gilbert, 2006; Minner, Levy, & Century, 2010). Ensuring these conditions foregrounds the need for detailed content–activity plans that guide teachers toward process-oriented instructional design.

Unlike the previous curriculum, "A Scientific Discovery Journey" has been introduced as a standalone unit in the Grade 3 curriculum, while "Journey into Science" has been added to the Grade 4 curriculum. Through these units, science education begins with an explicit focus on the nature of science, scientific process skills, curiosity, question asking, and exploration. In the earlier curriculum (MoNE, 2018), these elements were presented implicitly through dispersed outcomes; in the new curriculum (MoNE, 2024), they have been transformed into a distinct and intentionally designed structure. Similarly, the Grade 3 unit "Earth Scientists at Work" differs from the earlier "Let's Get to Know Our Planet" unit by placing students in the role of scientists and emphasizing process and practice. In the Grade 4 curriculum, the unit "Energy Detectives" consolidates previously separate units such as "Electrical Devices" and "Lighting and Sound Technologies" under a single integrated framework. In addition, "Sustainable Cities and Communities" appears as a newly introduced unit in the Grade 4 curriculum. Taken together, these changes indicate that the 2024 curriculum does not merely revise content, but rather reconceptualizes unit-level design in alignment with inquiry, experience, and real-life relevance, while also raising important pedagogical questions regarding implementation conditions and instructional support.

Another Innovation: The Curriculum's Skills Framework

The skill domains included in the Grade 3 and Grade 4 Primary School Science Curricula exhibit a multidimensional structure, encompassing subject-specific skills, conceptual skills, dispositions, social-emotional learning skills, values, and literacy skills. This skills framework, derived from the curriculum itself, aims to make visible the principles of progressive advancement across grade levels, cognitive deepening, and the increasing development of student autonomy (MoNE, 2024). In particular, Grade 3 places emphasis on foundational scientific process skills such as observation, classification, prediction, and play-based curiosity, whereas Grade 4 foregrounds more advanced cognitive and self-regulatory skills, including hypothesis formulation, model construction, inquiry, and self-efficacy. This pattern suggests that the curriculum structures skills not through horizontal repetition, but through a vertical and developmental logic.

The skills framework presented below has been systematically constructed through an analysis of the Grade 3 and Grade 4 Science Curricula (MoNE, 2024). For each grade level, prominent subject-specific skills, conceptual skills, dispositions, social-emotional learning dimensions, values, and literacy skills have been classified from a holistic perspective. This framework aims both to concretize the theoretical orientation of the curriculum and to provide an analytical reference that teachers can utilize in lesson design, activity development, and assessment–evaluation processes.

Grade 3 science curriculum skills framework

- ***Subject-Specific Skills***

Classification; making scientific inferences; inductive reasoning; conducting experiments; prediction based on scientific observation; prediction based on scientific data; scientific observation; use of evidence; operational definition

- ***Conceptual Skills***

Inquiry; generalization; deductive reasoning; synthesis; problem solving; observation-based prediction; critical thinking

- ***Dispositions***

Curiosity; creativity; truth-seeking; open-mindedness; analytical thinking; questioning; playfulness; systematic thinking; responsibility; focus; critical stance

- ***Social-Emotional Learning Skills***

Self-awareness; self-regulation; collaboration; communication; responsible decision making; self-adaptation (self-reflection); social awareness

- ***Values***

Respect; healthy living; diligence; responsibility; frugality; patriotism; sensitivity; compassion; patience; cleanliness

- ***Literacy Skills***

Digital literacy; data literacy; sustainability literacy; information literacy; visual literacy; arts literacy

Grade 4 Science Curriculum Skills Framework

- ***Subject-Specific Skills***

Conducting experiments; hypothesis formulation; prediction based on scientific observation; scientific modeling; making scientific inferences; inductive reasoning; scientific inquiry

- ***Conceptual Skills***

Reflection; inquiry; curiosity; self-efficacy; truth-seeking; analytical thinking; systematic thinking; observation-based prediction; critical thinking; comparison; problem solving; generalization

- ***Dispositions***

Curiosity; specialization; truth-seeking; open-mindedness; questioning; critical stance; self-efficacy; analytical thinking; systematic thinking; playfulness; creativity; original thinking; independence; self-confidence

- ***Social-Emotional Learning Skills***

Self-awareness; self-regulation; self-adaptation (self-reflection); collaboration; responsible decision making; communication; flexibility; social awareness

- ***Values***

Diligence; respect; healthy living; aesthetics; frugality; cleanliness; friendship; responsibility; patience; sensitivity

- ***Literacy Skills***

Information literacy; digital literacy; visual literacy; data literacy; arts literacy; sustainability literacy

The Implementability of the 2024 Science Curriculum: Opportunities and Constraints

The Science Curriculum updated in line with the Türkiye Century Maarif Model (TCMM) expects teachers to move beyond content transmission and to design multilayered and flexible instructional practices aligned with the skills framework, values, dispositions, interdisciplinary connections, and principles of differentiation. However, the literature on curriculum reform indicates that teachers often encounter substantial challenges in translating new curricula into classroom practice due to conceptual ambiguity, time pressure, and insufficient pedagogical guidance (Spillane et al., 2002; OECD, 2020). Studies conducted in the context of science education similarly show that innovative instructional approaches acquired through professional development processes may have limited sustainability under classroom realities and institutional pressures, leading teachers to revert to established instructional routines

(Tappel, 2023; Prenger et al., 2020). As a result, a noticeable implementation gap may emerge between the pedagogical transformation envisioned by the curriculum and actual classroom practices.

Similarly, although differentiated instruction has a strong theoretical foundation as a core component of inclusive education (Tomlinson, 2014), the realities of primary school classrooms often constrain its systematic implementation. Teachers report that structural factors—such as large class sizes, heterogeneous student profiles, limited instructional time, and increased planning demands—frequently result in differentiation being applied in partial and fragmented ways (Gibbs et al., 2025; Mengistie, 2020). Research conducted in the Turkish context also indicates that differentiation practices often remain at the level of intention, and that structural and institutional barriers hinder their translation into concrete pedagogical practices (Altun & Nayman, 2022; Tozak et al., 2025). These findings suggest that, for the differentiation principle articulated in the curriculum to be effectively implemented, teachers need access to concrete tools and structured support mechanisms.

The simplification of learning outcomes in the curriculum can be viewed as a meaningful orientation toward balancing cognitive load and supporting conceptual deepening. Nevertheless, evidence from curriculum reform research indicates that when simplified curricula are not accompanied by sufficient instructional guidance, there is a risk of superficial treatment of core concepts and increased inconsistency across implementations (OECD, 2020). Such conditions may deepen the divide between the intended curriculum and the enacted curriculum, leading to growing disparities in students' learning experiences across schools. Accordingly, for simplification to function as a pedagogical advantage, it should be supported by explicit guides that help teachers navigate pathways for conceptual progression and deepening.

The integration of artificial intelligence (AI) tools into science teaching offers significant opportunities for personalization and for supporting teacher decision-making; however, at the primary school level, it necessitates careful consideration of ethical and pedagogical boundaries. UNESCO highlights risks associated with the educational use of generative AI—such as data privacy, bias, misinformation, transparency, and age appropriateness—and advocates for a human-centered and ethical framework (UNESCO, 2023). In this context, the use of AI in primary science education should be positioned not as a substitute for teachers' pedagogical judgment, but as a supportive tool, structured through clear principles and instructional scenarios. From this perspective, the curriculum appears to require further elaboration in relation to AI integration. While sustainability and climate education have become indispensable components of contemporary curricula, teacher self-efficacy emerges as a significant limiting factor in these domains. Research shows that when teachers lack sufficient knowledge and self-efficacy regarding climate change and sustainable development, they tend to address these themes in a superficial manner (Plutzer et al., 2016; Stevenson et al., 2017). Accordingly, the extent to which the sustainability emphasis articulated in the curriculum

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is reflected in classroom practice depends largely on strengthening teachers' pedagogical competencies in this area.

Finally, socioeconomically disadvantaged regions—where skill-based and differentiated instructional approaches are most urgently needed—are often the contexts with the most limited implementation capacity. Teachers working in these settings report difficulties in sustaining innovative instructional practices due to large class sizes and limited physical and pedagogical resources (Mengistie, 2020; Gibbs et al., 2025). This situation underscores the need for scalable, low-resource, and context-sensitive instructional designs to ensure that the curriculum's goals of equity and inclusivity can be effectively realized in practice.

In conclusion, given that the 2024 Science Curriculum is to be implemented gradually, it is crucial that the implementation process be accompanied by the systematic documentation and reporting of practice-based experiences of teachers, students, and all relevant stakeholders. Capturing classroom-level enactments, instructional adaptations, challenges, and contextual variations will not only contribute to monitoring the fidelity and feasibility of the curriculum, but will also provide evidence-informed feedback to support its continuous refinement. Such practice-oriented reporting can serve as a critical bridge between the intended curriculum and the enacted curriculum, ensuring that the pedagogical principles articulated within the Türkiye Century Maarif Model (TCMM) are translated into sustainable, equitable, and context-responsive science teaching practices.

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ARTIFICIAL INTELLIGENCE IN EDUCATION

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What is Artificial Intelligence?

Although there is no single, universally accepted definition of artificial intelligence in the literature, its conceptual origins can be traced back to the 1940s. Artificial intelligence tools enable reasoning within structured scenarios and support problem-solving processes (Winston, 1992). From another perspective, AI refers to rapidly evolving technologies that influence all spheres of life and operate through algorithms capable of thinking like humans by mimicking mental processes and performing judgment and decision-making tasks (Nabiyev, 2021). With the advancement of AI, numerous activities traditionally carried out by humans can now be performed more efficiently by machines, creating significant benefits. Russell and Norvig (2010) similarly define AI as a field concerned with designing systems that execute tasks requiring human-like intelligence. Today, AI is embedded in a wide range of sectors, including medicine, e-commerce, education, finance, logistics, transportation, and agriculture (Komalavalli et al., 2020). As these technologies continue to evolve, they increasingly shape and transform various industries.

The historical development of artificial intelligence can be traced back to the pioneering ideas of Alan Turing, who is widely regarded as the first scholar to conceptualize the possibility of machine intelligence. By posing the question *“Can machines think?”*, Turing challenged prevailing assumptions and rejected claims that machines were incapable of thought. The term *artificial intelligence* was formally introduced within a theoretical framework at the Dartmouth Conference in 1956. However, technological limitations in the 1960s and 1970s led to a period of stagnation known as the “AI winter.” This slowdown not only reflected technical constraints but also reignited epistemological debates regarding the nature of intelligence—raising questions such as whether intelligence can truly be formalized or whether the human mind possesses an irreducible uniqueness.

From the 1980s onward, increases in computational power and the rediscovery of neural networks shifted AI from a technical curiosity to a broader social phenomenon. In Turkey, early AI research began in 1985 (Yılmaz, 1990). A major milestone occurred in 1997 when IBM's Deep Blue defeated Garry Kasparov, marking a symbolic turning point in machine intelligence (Campbell et al., 2002). Entering the 21st century, and particularly between 2000 and 2020, AI entered the era of machine learning and big data, during which deep learning, large-scale datasets, and generative models rapidly advanced. These developments transformed AI into an object of everyday ethical and societal debate. The growing prominence of natural language processing and generative systems was especially notable. For instance, OpenAI's GPT-3, with its 175 billion parameters, demonstrated unprecedented capabilities in understanding and producing human-like written language, signaling that AI had evolved from a computational tool into a system capable of meaningful linguistic generation. The historical trajectory of artificial intelligence is presented in Figure 1.

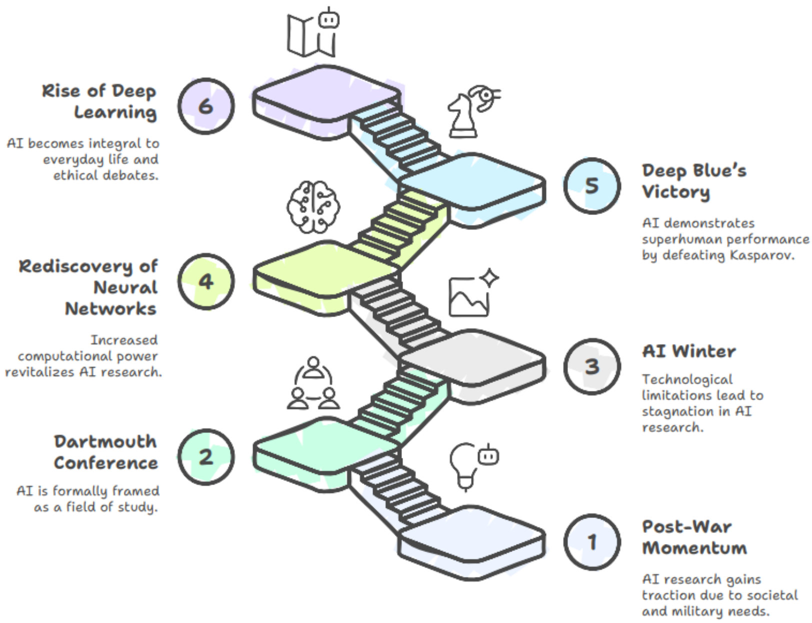

Figure 1. *History of Artificial Intelligence*

The year 2024 marked another leap, characterized by substantial improvements in scale, memory capacity, and integrative functionality. The success of contemporary models such as ChatGPT and BERT reflects not only technological advancement but also the redefinition of the boundaries of human cognition. However, the rapid growth of AI has simultaneously intensified concerns around security, prompting policymakers to emphasize AI-supported systems that safeguard personal data and protect citizens' digital rights. Although many nations view AI as a strategic instrument for accelerating economic and social development, significant differences persist in national policies and infrastructural readiness for AI deployment (OECD, 2023). Considering these dynamics, AI has clearly emerged as a new axis of global competition and geopolitical power.

Artificial intelligence is commonly classified into three categories in the literature: narrow, general, and super artificial intelligence. Narrow artificial intelligence, the most prevalent form of AI today, refers to systems designed to perform specific tasks with high efficiency (Pennachin & Goertzel, 2007). Known in the English literature as *Artificial Narrow Intelligence (ANI)*, this type of intelligence is based on machines developing deep specialization within a limited domain. Although such systems may engage in learning, their learning processes are restricted to predefined datasets; thus, they lack the human-like capacity for abstract reasoning or transferring knowledge across contexts. Examples include systems used for medical diagnosis, chess-playing programs, and mathematical theorem solvers (Pennachin & Goertzel, 2007).

General artificial intelligence (Artificial General Intelligence – AGI), on the other hand, denotes systems capable of human-level cognition, including thinking, reasoning, and learning (Dhokare, 2021). AGI is expected to integrate information and experiences from diverse contexts and adapt to novel situations. In this sense, an AGI system would be able to perform multiple cognitive tasks simultaneously—for instance, solving a complex mathematical problem while sustaining a natural conversation (Frank et al., 2017).

Artificial superintelligence (Artificial Super Intelligence – ASI) refers to systems that surpass human intelligence across all cognitive domains, including learning, reasoning, decision-making, and creativity. In the broader literature, this term is often associated with generative artificial intelligence, referring to systems capable not only of analyzing data but also producing original content or creative solutions (Frank et al., 2017). These systems generate human-like outputs rather than merely interpreting existing data, and therefore, generative AI is expected to bring profound transformations to the field of education.

Artificial intelligence also encompasses a broad set of subfields, including machine learning, artificial neural networks, deep learning, cognitive computing, and natural language processing, as well as the hardware and software components used within these domains (Varriale et al., 2025). As the literature has expanded, new classification frameworks have emerged. Pannu (2015), for example, organizes AI into several domains: language understanding, learning and adaptive systems, problem solving, perception and visual perception, modeling, robotics, and games.

The language understanding domain focuses on systems capable of interpreting, processing, and transforming human language. Learning and adaptive systems involve a system's ability to modify its behavior based on experience. Problem solving refers to methods used to represent a problem, plan a solution, and identify the data required for that solution. Perception, particularly visual perception, concerns the ability of AI systems to interpret sensory input and make sense of their environment. The model-based AI domain includes systems that construct internal representations of real-world phenomena and use these models to simulate processes. Robotics constitutes a higher-order field integrating AI capacities with physical movement and manipulation. The games domain applies AI to structured environments—such as chess or Go—where strategy formation, decision-making, and adaptive learning can be rigorously evaluated. Efforts to advance artificial intelligence for the benefit of humanity continue, and it is anticipated that numerous new AI subfields will emerge as the discipline evolves.

The Significance of Artificial Intelligence in Education

The digital transformation unfolding in the field of education has, in recent years, repositioned artificial intelligence (AI) from being merely a technological component to becoming a decisive force in reshaping instructional decision-making processes, learning experiences, and institutional policies. Key educational elements—such as curriculum design, data management, personalized learning, and assessment and evaluation—are increasingly conceptualized in alignment with AI-driven systems. In Türkiye, this transformation has been formalized through the National Artificial Intelligence Strategy articulated in the Ministry of National Education's 2024–2028 Strategic Plan, which identifies the development of human capital, the strengthening of data-driven governance processes, and the establishment of AI-based learning environments as priority areas (MoNE, 2025).

The range of AI applications in education is notably broad. The literature highlights AI's potential to support personalized learning environments, analyze educational data, adapt instructional materials, develop intelligent tutoring systems, automate assessment processes, and design supportive technologies for learners with special needs. Current research trends indicate that AI studies predominantly focus on student learning and individualized instruction. Çetin and Aktaş (2021) note that student-centered applications dominate the field, while AI scenarios related to school and classroom management are viewed as emerging areas for future development. According to Berson and Berson (2023), artificial intelligence—particularly generative tools such as ChatGPT—holds transformative potential for social studies education by supporting instruction, enhancing critical thinking, and strengthening ethical awareness within innovative learning environments. Wee et al. (2022) found that the integration of artificial intelligence significantly enhances instructional quality in music education, optimizes learning environments, and modernizes teaching practices. Lin et al. (2024) revealed that AI applications foster creativity by offering new ideas and problem-solving strategies, enhance engagement through interactive features, support learning with personalized feedback, and contribute to emotional well-being through gamification and constant availability, while quantitative findings further confirmed that teachers and students generally hold positive attitudes toward the opportunities and challenges presented by these technologies. Zawacki-Richter et al. (2019), in their review of AI in higher education, classify existing applications into four categories: adaptive systems, assessment and evaluation, student profiling and prediction, and intelligent tutoring systems. Similarly, Verma (2018) emphasizes AI's expanding roles in grading, feedback provision, identifying learning difficulties, transforming teacher roles, and strengthening student support mechanisms.

At the same time, the ethical, pedagogical, and social dimensions of AI in education have become central areas of inquiry. Concerns such as student data privacy, algorithmic bias, the reconfiguration of teacher roles, and the transparency of AI systems lie at the heart of ongoing debates regarding the widespread adoption of AI technologies in educational settings (Selwyn, 2019). Consequently, policy efforts aimed at integrating AI into education must extend beyond technological infrastructure to encompass pedagogical transformation, ethical awareness, and enhanced teacher competencies (Zawacki-Richter et al., 2019).

The gradual integration of AI into education systems across many countries suggests that learning processes will increasingly evolve into AI-supported structures in the future. In Türkiye, the development of digital educational materials beginning in 2019—starting from the primary school level—represents a significant milestone in this transformation. Furthermore, the establishment of the Department of Artificial Intelligence and Big Data Applications within YEĞİTEK in 2025 marks an important institutional effort to consolidate data-driven decision-making and digitalization processes under a unified organizational framework.

AI applications offer considerable potential to enhance the quality of educational environments by enabling learning processes that are more flexible, data-informed, and individualized. However, the integration of AI into education introduces not only opportunities but also a set of challenges that require careful attention. Sustaining digital transformation in education, therefore, depends on strengthening programs designed to improve AI literacy among both preservice and in-service teachers. Enriching teacher education with applied components that teach how AI tools can be integrated into pedagogical design is critical in this regard (Işık & Köse, 2025). For preservice teachers, viewing AI not merely as a content-generating technology but as a *pedagogical partner* that supports teaching and learning processes can enhance their capacity to manage future classroom environments more effectively. For practicing teachers, professional development initiatives that foster proficiency in using AI tools—and enable their adaptation to local educational contexts—are likewise essential.

AI-Supported Learning Environments in Education

In recent years, rapid advancements in artificial intelligence (AI) technologies have profoundly transformed science education, particularly in the areas of instructional design, assessment processes, and learner support systems. Three primary categories of AI—intelligent tutoring systems, expert systems, and natural language processing–based chatbots—emerge as the most widely examined applications in educational research. AI-powered personalized learning platforms, for instance, have the capacity to analyze students' learning pace, errors, and levels of conceptual understanding, thereby continuously adapting content and activities to meet individual needs (İncemen & Öztürk, 2024). Such systems help reduce conceptual misunderstandings in science education by providing tasks and feedback tailored to learners' specific difficulties, ultimately optimizing the learning process (Yıldırım & Arıcıoğulları, 2024; Şimşek, 2017).

Another increasingly widespread AI tool in science education research involves AI-supported virtual reality laboratories and simulations. These applications provide interactive environments where students can engage with scientific concepts when access to physical laboratories is limited. They allow learners to make mistakes, observe outcomes, and develop modeling skills in a safe virtual environment. In chemistry education, for example, AI-based simulations support the visualization of molecular processes, the modeling of abstract concepts, and the safe execution of high-risk experiments in virtual settings (Elmas & Geban, 2012; Martin & Graulich, 2023).

The literature further suggests that AI tools in science education—particularly in fields such as physics, chemistry, and biology where abstract concept density is high—facilitate the early detection of misconceptions by providing real-time feedback (İncemen & Öztürk, 2024). Additionally, studies indicate that high-quality science instruction contributes to students' career awareness and supports the design of lessons aligned with STEM approaches emphasized in curricula (Ergün & Bilen, 2020; Çakmak et al., 2019; Doğan et al., 2020). Therefore, it is crucial to design effective instructional experiences across all grade levels, given the direct relevance of science knowledge to students' daily lives. At this point, AI tools play a significant role in making abstract concepts more concrete. AI-based simulations and VR/AR laboratories enable students to repeatedly execute experimental processes in safe environments and interactively examine molecular structures and reaction mechanisms—thus fostering scientific modeling and explanation skills (Buluş & Elmas, 2024).

AI-supported teacher assistants also offer substantial advantages in identifying students' conceptual difficulties, facilitating differentiated instruction planning, and conducting assessment tasks using data-driven insights (Coşkun & Küçükali, 2021). These tools greatly assist teachers in monitoring individual student progress. However, educators must be supported in developing competencies related to the effective use of such tools and in evaluating AI-generated recommendations from a pedagogical perspective. Indeed, the literature highlights that both teachers and preservice teachers require additional support in integrating AI tools into science instruction (Nazalı, 2025). Studies conducted at the K–12 level reveal that research on improving AI competencies among teachers or teacher candidates remains limited, with most studies instead focusing on the technical skills to be taught and the possible AI tools that may be used (Li et al., 2024).

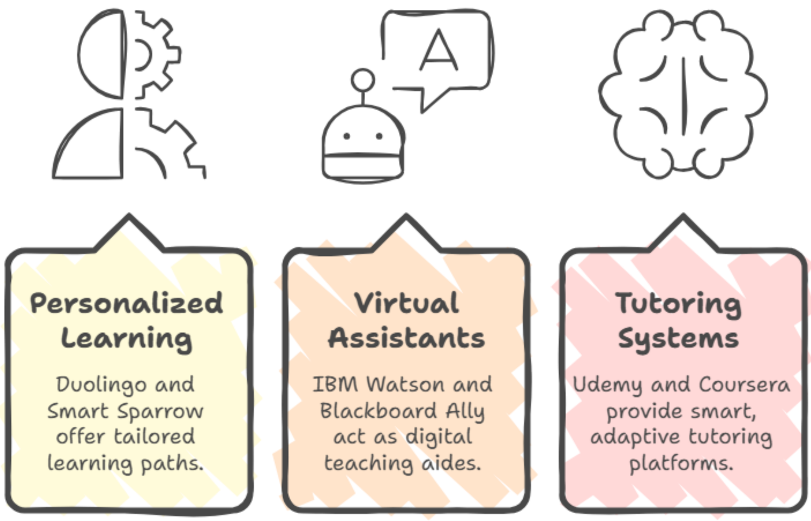

Figure 2. *Selected artificial intelligence tools used in science education*

The integration of the artificial intelligence tools shown in Figure 2 into classroom instruction is closely linked to teachers' AI literacy. This highlights the importance of designing well-structured professional development activities in this context.

Artificial Intelligence Literacy

Artificial intelligence (AI) literacy is defined as individuals' ability to make informed decisions when interacting with AI, interpret system behaviors, and contextualize technologies within their broader societal functions (Long & Magerko, 2020). AI literacy represents a multi-layered competency that encompasses not only the ability to use AI technologies but also the capacity to understand how such systems operate, evaluate their outputs, recognize ethical risks, and apply them conscientiously for pedagogical purposes.

In Türkiye, the Ministry of National Education's *Policy Document on Artificial Intelligence in Education* (2025) identifies AI literacy as a core component of digital transformation and emphasizes it as a critical requirement for all stakeholders. Likewise, the recently implemented *Maarif* curriculum underscores the importance of a human-centered approach to education, highlighting the need to position AI as a pedagogical tool rather than merely a technological add-on. Within this framework, AI literacy is conceptualized as an essential digital competence for all stakeholders—students, teachers, school leaders, and parents alike.

International literature also conceptualizes AI literacy as a holistic competence that transcends basic "technology use" and integrates technical knowledge, ethical awareness, critical evaluation, and implementation skills (Kong et al., 2023). Accordingly, positioning AI literacy as a foundational component of future educational ecosystems requires a comprehensive approach that supports safe, informed, and critical engagement with technology. In science education, process skills such as data literacy, modeling, algorithmic thinking, and scientific reasoning are already central elements; thus, AI literacy emerges as a natural extension of these skills. Science education provides a particularly powerful context for developing AI literacy, as it enables students to learn how algorithms make decisions, understand that data may contain error or bias, and critically evaluate the limitations of technological tools through the lens of scientific inquiry.

For this reason, strengthening science educators' own AI literacy is crucial for fostering conscious and ethical AI use among future learners. Equally important is ensuring that students have free access to the Internet, computers, and AI tools. Many countries are actively investing in the necessary infrastructure to support students' access to AI technologies in schools and are publishing research on this topic. A consistent finding across these studies is the emphasis on teachers' access to AI tools. Teachers' ability to employ AI tools in the classroom—while attending to ethical considerations and demonstrating the competencies encompassed by AI literacy—has been shown to enhance the effectiveness of AI-based educational practices (Long & Magerko, 2020; Wang et al., 2022).

The Ethical Dimensions of Artificial Intelligence

Ethics is defined as a system of thought grounded in societal norms that guides judgments about what is right and wrong. While moral rules may vary across cultures, ethics seeks to interpret these rules through rational inquiry. In this sense, ethics functions as a higher-order construct that encompasses morality. Throughout history, various ethical theories have emerged, including utilitarian, deontological, and ecological frameworks that are commonly referenced in decision-making processes (Miles & Hubermann, 1994). For example, ethical approaches that prioritize societal benefit are often characterized as deontological ethics. Although artificial intelligence technologies provide numerous societal and individual benefits across many domains, ethical concerns have become increasingly prominent. Indeed, debates continue about how to design and implement ethically aligned AI systems (Uyar, 2019).

Within the context of education, the rapid expansion of AI technologies has brought forth not only pedagogical advantages but also significant ethical and practical risks. One major concern is the growing reliance of students on AI tools to access information, generate content, or complete assignments—fueling fears that human intelligence may gradually be displaced by technological systems (Vashistha & Harikrishnan, 2025). Ethical debates surrounding AI typically center on three major risk areas: data security, algorithmic bias, and academic integrity (Holmes et al., 2021). When student data analyzed by AI systems are misused, they present substantial risks to both privacy and security. Excessive dependence on AI for academic assignments also undermines academic integrity and obscures the fundamental purpose of learning.

Kulkarni, Cambre, Kotturi, Bernstein, and Klemmer (2013) caution that AI tools may be misused by students to automate or simplify assignment preparation, thereby significantly diminishing the quality of learning. Similarly, Ma, Wan, and Lu (2008) argue that the ability of AI tools to complete academic tasks on behalf of learners may compromise the value of learning and render educational objectives ineffective. Therefore, ensuring trustworthy AI use in education necessitates the establishment of systematic ethical guidelines for educators, administrators, and students. Adopting an interdisciplinary approach is expected to strengthen ethical awareness and promote more equitable, transparent, and accountable AI applications.

In this regard, the Ministry of National Education has published the *Guideline for Ethical Use of Artificial Intelligence Applications* (2025b). This document specifies the ethical framework within which AI tools used in educational settings must be evaluated. The principles outlined emphasize that all AI applications should be designed in accordance with equity, inclusiveness, and accessibility. Privacy, security, and confidentiality are identified as core priorities in AI systems. Another key principle highlights that AI tools must be transparent, traceable, and accountable in their decision-making processes; users should be able to understand how AI applications operate, what data they utilize, and the types of outputs they generate. This transparency enables both teachers and students to make more informed decisions when interacting with technology.

Furthermore, the guideline states that AI applications should contribute meaningful pedagogical value, not merely offer practical convenience. AI content and usage practices must not conflict with the foundational values of the educational system, and teachers, students, and administrators must be informed about the risks and limitations of AI. The principles outlined in the guideline are summarized in Figure 3.

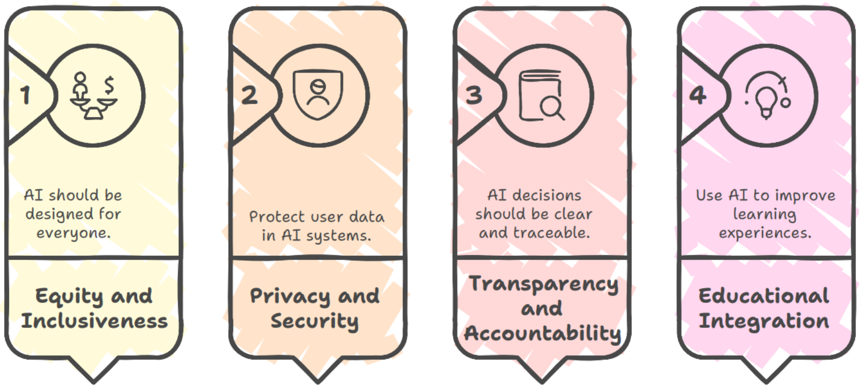

Figure 3. *Summary of the principles highlighted in the Ethical Guidelines for Artificial Intelligence Applications (MoNE, 2025b)*

In conclusion, the sustainable and responsible use of AI in education depends on the consistent implementation of ethical guidance mechanisms and the active development of awareness among all stakeholders. When this coherence is achieved, artificial intelligence technologies can become inclusive, trustworthy, and genuinely value-adding tools within the educational system.

From National and International Perspectives: AI-Driven K-12 Education Policies

The sustainable and responsible use of AI in education depends on the consistent implementation of ethical guidance mechanisms and the active development of awareness among all stakeholders. In brief, strengthening students' AI literacy requires establishing an AI education ecosystem that covers not only undergraduate and graduate levels but all stages of schooling. Accordingly, in recent years, several countries (e.g., the United States, the United Kingdom, Finland, China, Australia, and South Korea) have initiated practical efforts aimed at integrating AI into K–12 education (Kandlhofer, 2016; Karaca & Kılcan, 2023). Initiatives designed to expand basic understanding of AI technologies at the K–12 level have gained importance in both theory and practice (Ho et al., 2019). A review of the research on the inclusion of artificial intelligence in K–12 curricula reveals several common considerations. These include instruction on fundamental AI concepts to provide students with a solid foundation, teaching about the ethical and societal implications of AI, offering hands-on learning experiences, and emphasizing AI tools and games that allow young learners to gain early experience with AI technologies (Yue et al., 2022).

Van Brummelen, Heng, and Tabunshchyk (2021) further argue that the increasingly systematic inclusion of AI education in K–12 programs is essential, particularly emphasizing competencies such as AI literacy, computational thinking, ethical awareness, and understanding of machine learning processes. Research also shows that AI in education enhances students' interest, attitudes, and motivation (Yue et al., 2022). However, it remains crucial to conduct long-term, large-scale studies on the topic. Program development efforts aligned with age-appropriateness and societal needs, along with evaluating results from different countries, are necessary for structuring effective curricula.

Today, AI technologies lie at the center of global competition. Therefore, integrating AI into K–12 curricula in our national education system and updating programs when needed is not only an educational necessity but also a strategic political priority. One of the most notable examples in this regard is South Korea's National Artificial Intelligence Strategy, published in 2019. The strategy announced that specialized AI training programs would be offered to teachers at different school levels to improve their AI-related competencies and that AI-supported digital textbooks would be gradually implemented in mathematics, computer science, and English courses starting in 2025. The primary purpose of these digital textbooks is to provide students with personalized learning experiences through instructional materials (Kim, 2025).

A similar approach is seen in Finland, which launched the free online course "Elements of AI" to democratize access to foundational AI concepts for the entire population (Paek & Kim, 2021). As seen across multiple countries, various initiatives are being taken to integrate AI into K–12 education. In this context, establishing a well-grounded AI education model from early ages emerges as a critical requirement for cultivating a qualified future workforce and achieving national development goals.

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EXECUTIVE FUNCTIONS AND SCIENCE EDUCATION IN CHILDREN WITH SPECIAL EDUCATIONAL NEEDS

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INTRODUCTION

The Universal Declaration of Human Rights and the constitutions of many countries emphasise that the right to education is a fundamental and inalienable right for every individual (Assembly, 1949; OECD, 2018). In this context, the concept of equal opportunity has also gained vital importance for students. The concept of equal opportunity refers to areas shaped more by social demands and expectations, such as education, health, social security, and employment, where every individual can have access under equal conditions without any discrimination (UNESCO, 2017). Establishing equal opportunities in education has a much more strategic importance than other areas, as it has the potential to bring about fundamental changes in an individual's status in many areas, such as income level and employment opportunities, in terms of the outcomes achieved (Hanushek & Woessmann, 2023; İnan & Demir, 2018).

Alongside the principle of equal opportunity, 21st-century skills have also become an indispensable component of education, particularly with the adoption of the constructivist approach in our education system (Fosnot, 2013; OECD, 2018). Constructivism is based on the principle of effectively using prior knowledge in the formation of new meaning-making processes (Nunes & McPherson, 2003). In other words, individuals do not passively receive knowledge from outside; instead, they reconstruct knowledge within their own mental schemas. Individuals learn by blending new knowledge with their existing prior knowledge and adapting this knowledge to their own cognitive processes (Özden, 2008). One of the fundamental objectives of this approach is equipping students with 21st-century skills and enhancing the quality of the meaningful learning process (Trilling & Fadel, 2009). 21st-century skills refer to the set of competencies that enable individuals to be active citizens and qualified workers in today's information society (Cansoy, 2018). These skills are frequently classified in the literature as Collaboration, Communication, Critical Thinking, and Creativity. These skills will be examined in turn in the following sections (Trilling & Fadel, 2009).

Collaboration

Collaboration is a form of learning and working that involves individuals working together towards a common goal or plan when it would be difficult for one person to achieve it alone (Johnson & Johnson, 2009). The aim is to complete certain tasks in a more systematic and efficient manner. While collaboration appears in many areas of daily life, in an educational context it is referred to as 'collaborative learning'. In this model, students are encouraged to divide tasks among themselves to serve a common goal in the implementation of an achievement or project. During this process, a strong link is established between individual success and group success; lasting learning is supported through social interaction (Gillies, 2016). Thus, the perception of 'I' gives way to the perception of 'we', supporting the connection of teaching to life and increasing lasting learning.

Communication

When examining the life cycle from the past to the present, it is seen that humans, animals, and even plants sustain their existence through constant and dynamic interaction with their environment. Ensuring the continuity of this interaction necessitates certain patterns of action and behaviour; the phenomenon of communication has developed from this fundamental requirement. The verbal expressions, physical movements, and facial expressions used in this process can be characterised as strategic communication choices that individuals resort to in conveying their feelings and thoughts (Burleson, 2010).

When considered in the context of education, communication skills are of undeniable importance, both on an individual (private) and general level. Particularly within the framework of 21st-century competencies, peer interaction among students, pedagogical dialogue between teachers and students, and international scientific communication that transcends borders have become central to educational processes. In this context, communication skills have evolved beyond being merely a tool for daily interaction; they have become a fundamental component of 'scientific literacy', encompassing processes such as the interpretation of complex data, the correct use of scientific terminology, and the sharing of findings (Norris & Phillips, 2003).

Critical Thinking

Critical thinking is a higher-order form of thinking that involves mental processes such as reasoning, analysis, and evaluation, questioning information rather than accepting it directly (Facione, 2011). It is the activity of recognising and understanding a problem without believing in fallacies or reaching definitive conclusions (Erdamar & Alpan, 2017). In this context, individuals move away from the assumption that the information presented is absolutely true and filter this information through their own cognitive filters via research and thinking processes. This competency, which is indispensable in our education system, especially in science education, not only increases students' curiosity about science but also lays the groundwork for them to acquire a scientific identity and an investigative attitude in the future. In the context of science education, critical thinking is a fundamental competency in terms of students developing scientific curiosity, forming hypotheses, and acquiring scientific reasoning skills (Kuhn, 2010).

Creativity

Creativity is the ability to process inputs differently, perceive the world differently, and function as an original system in order to improve the existing situation and bring innovation in any field. This innate potential can be discovered and developed with the right environmental conditions and education (Yeşilyurt, 2020). In educational science literature, this perspective, represented particularly by Jerome Bruner, is supported by the concept of 'intuitive thinking'. In this approach, Bruner argues that learning should not be the direct presentation of ready-made knowledge, but rather a process of discovery in which the learner makes an effort to access knowledge. Therefore, creative thinking skills eliminate uniformity in educational environments, transforming the process into active participation and lasting learning outcomes, thus making learning more meaningful.

The basic definitions of these skills, outlined in the conceptual framework above and referred to as "4Cs", reflect general educational goals designed for individuals with typical development. However, when these skills are considered in the context of special education, it is inevitable that various limitations will be encountered in the transfer process. In particular, questions arise regarding how to instil higher-order cognitive processes such as the concretisation of abstract concepts, critical thinking, and creativity in students with special needs, and how to plan inclusive education in this process.

At this very point, science education offers a strategic solution area with its constructivist approach and its nature that supports 21st-century competencies. As is well known, science teaching differs from other disciplines in that it is linked to life itself rather than being a theoretical process confined within classroom walls. For example, using examples from daily life when examining a natural phenomenon or conveying physical concepts such as friction allows knowledge to be made concrete. In this way, science education provides an effective and supportive learning environment for individuals with special needs by addressing events not only in a result-oriented manner ("it happened and it's over") but also in a process-oriented manner, analysing factors, questioning "how" and "why" questions, and the generation of innovative ideas.

This section is a conceptual compilation of national and international literature addressing the relationship between executive functions and science education in children with special needs. The study did not follow an experimental method; existing theoretical approaches and current research findings were discussed within a holistic framework. The 21st-century skills and constructivist approach discussed so far provide a template for what education should be and how it should be delivered. However, the main focus in the special education process should be on the cognitive infrastructure that enables students to demonstrate these skills. This infrastructure is defined in the literature as Executive Functions. Executive functions are self-regulation skills that individuals use to reach a goal that is not easily accessible, including planning, organisation, problem solving, utilising working memory, changing set, and inhibition (Çiftçi et al., 2020).

In light of this definition, none of the 4C skills (Collaboration, Communication, Critical Thinking, Creativity) discussed in the previous sections are independent skills; rather, they are all governed by executive functions. For example, to be able to collaborate, one needs "impulse control"; to think critically, one needs "working memory" capacity; and for creativity, one needs "cognitive flexibility". Therefore, executive skills are a metacognitive management mechanism that determines how a subject will be approached, when and why the process will be planned, and with which strategies, ultimately resulting in the creation of a tangible product.

In the context of special education, the primary goal is to equip students with the "executive" capacity to process this information rather than simply imparting academic knowledge. Science teaching, by its very nature, provides the most natural and effective learning environment for the development of executive functions through the "Scientific Process Skills" (observation, classification, prediction, experimentation) it inherently encompasses. This is because planning a science experiment uses the same neurological pathways as planning a behaviour. For example, a student with special needs arranging materials in sequence (planning), focusing their attention on the outcome (inhibition), and reaching a conclusion by testing their hypothesis in a simple circuit-building experiment means that abstract executive skills are rehabilitated and strengthened through a concrete science activity.

Conceptual Framework

The importance of executive functions in education was briefly discussed in the introduction. This section examines the basic components of executive functions and their relationship with science teaching in detail.

Working Memory

When examining the historical development of the educational process, it is evident that teaching methods have evolved from a linear transfer of knowledge to a multidimensional knowledge construction process (Fosnot, 2013). In the traditional educational paradigm, the teacher was the sole source and active transmitter of knowledge, while the student was a passive recipient who accepted knowledge without question. During this period, lessons were often taught in a uniform manner, disregarding students' readiness levels, cognitive awareness, or learning styles (such as Multiple Intelligence Theory). However, as we approach the present day, the teacher's role has first evolved into that of a guide through 'discovery-based teaching'; and in the 21st century, with the adoption of the constructivist approach, the student has risen to the position of being the architect of knowledge (Piaget & Inhelder, 2008; Von Glasersfeld, 2013).

In this new process, where the student actively processes knowledge rather than passively storing it, a critical cognitive mechanism comes into play for lasting learning to occur. This mechanism is referred to in the literature as "Working Memory". Working memory is a cognitive system with limited capacity that enables the temporary storage and simultaneous processing of information during complex cognitive tasks (Eren, 2024).

Based on this definition, working memory, unlike short-term memory, is not just the retention of information in the mind, but also the process of making it meaningful by relating it to past experiences (long-term memory). According to Baddeley's (2000) model, which is the most widely accepted in the literature, this process is not managed from a single centre. Working memory consists of subcomponents such as the 'phonological loop' (e.g., repeating the teacher's instructions internally), where verbal data is held, and 'visuospatial sketching' (e.g., visualising the experiment diagram on the board in one's mind), where visual data is processed. The coordinated functioning of these components is essential for the information to be correctly encoded into long-term memory. To illustrate this, a 'cook' metaphor can be used: it is not enough for a cook to simply recognise the ingredients (information storage); to produce a delicious meal, they must instantly plan and manage which ingredient to add to the pot, in what order, how much, and when. This "kitchen counter" in the student's mind is the working memory (Baddeley, 2000).

Science teaching, by its very nature, requires the simultaneous retention and processing of multiple variables (formulas, observations, cause-and-effect relationships) in the mind, making it an area where working memory is most intensively used. For example, consider a student seeking an answer to the question, "What is the importance of water in our lives?" It is not enough for this student to remember the chemical structure of water (H_2O), its cycle in nature, and its place in human biology separately; they must hold this information in their mind simultaneously and combine it to reach the conclusion that "water is indispensable for life" (Sweller et al., 2011).

It is known that working memory capacity may be limited in individuals with special needs, which directly affects academic learning (Alloway et al., 2009). Therefore, in science education, presenting information in parts, using concrete materials, and in a step-by-step manner is considered a critical teaching strategy in terms of supporting executive skills.

Inhibition (Impulse Control) and Focus

In educational processes, managing "how" and "when" to use these acquired competencies is as essential as the method of learning, the teacher's guidance, and the interpretation of information. A student's possession of knowledge does not mean that they can use that knowledge in the right context;

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this is where the mechanisms that manage a person's impulses and attention come into play. The first of these mechanisms is referred to in the literature as Inhibition. Inhibition is the ability to consciously stop one's automatic responses, resist distractions, and control behaviours that are not appropriate for the purpose (Çiftçi et al., 2020). Thanks to this ability, students delay their immediate desires (delaying gratification) and use information at the expected time and in the appropriate context.

Science teaching, by its very nature, involves intriguing materials and experiment sets, making it the area where inhibition skills are most intensely tested. For example, imagine a science lesson where the teacher has placed experiment sets on the desks. A student who has done the experiment before or is impatient to touch the materials must give themselves an internal "stop" command and not start the experiment before the teacher has finished their instructions. Despite this student's excitement, controlling their impulse and listening to the teacher, then acting in harmony with their group mates, is an example of successful inhibition (Hofmann et al., 2012). However, in individuals with special needs, this "cognitive brake" mechanism may be weak. In science laboratories, this situation may pose not only an academic problem but also a safety risk. For example, in risky processes such as acid-base experiments, the student's impulse to touch the material without wearing protective equipment can lead to serious accidents (Barkley, 2012). Therefore, the healthy functioning of the 'learning by doing' process in science lessons is directly dependent on the student's ability to suppress motor impulses (motor inhibition).

Another critical process that must be addressed alongside inhibition and that complements it is concentration. Concentration is the directing of mental resources towards a specific task or stimulus and, in this process, filtering out and ignoring external factors that could distract attention (Karatay, 2020). Today, the classroom environment is full of challenging stimuli, especially for students diagnosed with attention deficit hyperactivity disorder (ADHD) or those experiencing focus issues. The variety of materials in science lessons, noise during group work, or movement within the classroom can become a chaotic background that dampens the learning enthusiasm of a student experiencing concentration difficulties. When classroom management is inadequate or environmental noise is high, it becomes difficult for the student to direct their mental resources towards the relevant stimulus (e.g., the teacher's voice or the outcome of an experiment). Therefore, developing the ability to focus as part of executive skills is a prerequisite for science education, enabling the student to filter out the "noise" of the outside world and lock onto the actual object of learning (Willcutt et al., 2005).

Cognitive Flexibility and Problem Solving

Students' ability to control their impulses (inhibition) and focus their attention prepares the necessary groundwork for learning; however, for learning to take place, powerful cognitive tools are needed to work on this groundwork. Cognitive skills such as reading, remembering, and reasoning form the brain's capacity to process information. However, the real difference lies in how "aware" and "flexible" an individual is in using these skills when faced with a problem. The fact that each student's response to a problem and the defence mechanisms they develop are different can be explained by their levels of cognitive awareness. A problem that seems "insurmountable" to one student may be a simple step for another student who can change their strategy (Diamond, 2013; Miyake et al., 2000).

This is where cognitive flexibility, the most dynamic component of executive functions, comes into play. Cognitive flexibility is the ability to adapt to changing environmental conditions and new situations, develop different perspectives, and generate alternative solutions to problems encountered (Öztürk, 2019). Science education, by its very nature, has a structure that is not static and is constantly updated, making it one of the disciplines where cognitive flexibility is most intensively used. We can examine this situation through two basic examples:

Idealised Problems vs. Reality: In science, particularly in chemistry lessons, gas problems or solutions are often taught under idealised conditions such as 'Under Normal Conditions (UNC)'. However, conditions in the real world are variable. A student with high cognitive flexibility can modify their knowledge according to changing temperatures, pressures, or external factors and adapt it to the new situation, rather than rigidly memorising the rules they have learned.

The Changeability of Scientific Knowledge (Nature of Science): The history of science is a history of change. The historical development of atomic models is the most striking example of this. The transition from Dalton to Thomson, and from Rutherford to the Modern Atomic Theory, demonstrates how knowledge is constantly updated through falsification. Although this transformation appears to have taken place over many centuries, for the student it is a rapid paradigm shift that occurs in just a few pages of a textbook. For an individual with a rigid mindset who assumes that underlying knowledge is "absolute and unchanging," this change is confusing. However, individuals with cognitive flexibility quickly adapt to the new model by understanding "why the old model was inadequate" and internalise this dynamic nature of science.

In this context, cognitive flexibility is inseparable from problem-solving skills. Research shows a strong and positive relationship between cognitive flexibility and problem-solving skills. Individuals with high levels of cognitive flexibility do not get stuck on a single solution path when faced with problems; they produce alternative solution paths and exhibit more effective and rational problem-solving styles (Buğa et al., 2018). Consequently, the goal in science education is to cultivate solution-oriented individuals who not only apply formulas but also question the reasons behind the positioning of subatomic particles in different models and generate alternative approaches if one path to the solution proves unfeasible.

Up to this point, 21st-century skills (4Cs), the core components of executive functions (Planning, Working Memory, Inhibition, Cognitive Flexibility) and their theoretical relationship with science education have been detailed.

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Once the general framework has been outlined, the main question to focus on is: How do all these complex cognitive processes and higher-order skills correspond to the world of children with special needs? How can science education act as a lever to support the executive skills of students in this particular group? The following section will address this integration process and implementation strategies.

Current Situation and Challenges

The term "special needs" in today's literature refers not only to a medical diagnosis but also to a much broader sociological and educational perspective. In its simplest form, special needs can be defined as an individual deviating from standard developmental patterns, viewing the world through their own unique lens (a personal pattern) and perceiving the world based on these differences. These differences can manifest in physical, mental or sensory areas. The fact that differences between individuals are so pronounced and varied necessitates that the communication we establish with the "special" children mentioned in our title and the educational processes we design also deviate from the standard and become "special".

Focusing on the definition in the literature, children with special needs are "children who, for various reasons, show significant differences from their peers in terms of individual characteristics and educational competencies and therefore require special education services (Akkaya & Güçlü, 2018). In light of this definition, the educational needs and learning abilities of children with special needs differ significantly both from their typically developing peers and among themselves (intra-group diversity). This diversity also plays a decisive role in the organisation of educational environments. Today's educational policies are based on the principle of the "Least Restrictive Environment". Accordingly;

- Some students with special needs are competent to continue their education in the same classroom as their peers (Full-Time Inclusion/Integration) with the necessary support services provided.

- Some students, however, continue their education in classes formed with groups showing similar characteristics (Special Education Classes) in segregated environments according to their level of need (Ministry of National Education [MEB], 2018).

The decision-making process regarding which educational environment special needs students will be placed in is carried out through the coordination of the Special Education Assessment Boards within the Guidance and Research Centres (RAM) and the Psychological Counselling and Guidance (PDR) services in schools. These units adhere to the principle of the 'Least Restrictive Environment' when determining the most suitable educational environment for the student (MEB, 2018).

To outline a general framework: students whose cognitive processing processes, adaptive behaviour skills, and academic follow-up potential are close to their peers, and who do not have severe sensory (vision/hearing) loss that would directly hinder the educational process, continue their education alongside their peers in mainstream education classes as 'Inclusion/Integration' students. In contrast, students with more pronounced limitations in their cognitive, academic, or adaptive skills continue their education in "Special Education Classes," where more intensive individualised support is provided, through the joint efforts of special education teachers and support service specialists (counsellors, speech therapists, etc.) (MEB, 2018). Regardless of the environment, the development of these students' executive skills and science teaching processes necessitate differentiated strategies compared to their typically developing peers (Diamond, 2013). At this point, in order to integrate science teaching with executive functions, it is necessary to first examine the diagnostic groups that cause the student's "difference" and the cognitive characteristics of these groups.

Specific Learning Difficulty

When examining educators' general perceptions of learning problems, the cause of failure is usually based on two fundamental assumptions: either insufficient classroom interaction or the student's low cognitive capacity. However, there is a third group that is frequently encountered in science classrooms but is often misinterpreted. This group consists of students who, despite having no mental impairment, exhibit a significant gap between their academic performance and their potential. It is precisely at this point that the neurobiological differences defined in the literature as Specific Learning Difficulties (SLD) come into play.

Specific learning difficulties are developmental difficulties in areas such as reading, writing, mathematics, attention, and memory that are neurologically based, despite having normal or above-average intelligence (Ulkuer & Tutuş, 2023). This definition points to a critical paradox for educators: while the student may be ahead of their peers in terms of conceptualising science topics in their mind, establishing cause-and-effect relationships or scientific curiosity, they may be unable to demonstrate their performance due to neurological disconnections in the channels of information intake (input) or expression (output) (American Psychiatric Association [APA], 2025a). Specific learning difficulty is an umbrella term that encompasses subtypes affecting science education in different dimensions (APA, 2025a):

- ***Dyslexia (Reading Difficulty):*** Science education requires intensive terminology and following instructions. For example, a student who wants to set up an experiment at home or in a laboratory environment may be unable to decipher the text due to letters being transposed or syllable combinations being mixed up while reading the instructions. Despite having the mental capacity to conceptualise the experiment, they may be labelled as a failing student who cannot build a simple circuit simply because they cannot "decode the reading".

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- ***Dyscalculia (Mathematics/Arithmetic Difficulty):*** Science subjects rely on the interpretation of quantitative data in physics, chemistry, and biology. A student with dyscalculia, who struggles to understand mathematical symbols or calculation steps, may be perceived as not understanding the science concept (e.g., what force is) when they struggle with the stoichiometric calculation of a chemical reaction or force calculations in physics. However, the problem lies not in the concept, but in the language of the concept, which is mathematics.

- ***Dysgraphia (Writing Difficulty):*** Motor and organisational difficulties experienced in the processes of noting down or reporting observation results can also overshadow science achievement. These difficulties may cause the student to experience "learned helplessness" towards the subject and develop an emotional coldness towards science (Sideridis, 2003). Furthermore, the excessive mental effort expended in reading a text or performing a task fills the student's "Working Memory" capacity, leaving no room for the scientific concept that should be the main focus (Sweller et al., 2011).

Attention Deficit Hyperactivity Disorder (ADHD)

Looking back on our school years, most of us recall a familiar silhouette: the "naughty" child in the class. The child who was constantly warned by teachers, who could never sit still, who was always in the spotlight with their voice and movements... Such behavioural patterns are among the experiences that many individuals encounter during the education process. Behind these behavioural patterns, which have been labelled as "undisciplined" or "unmotivated" for years, lies a neurobiological necessity that transcends the child's will. This condition is defined in educational literature as attention deficit hyperactivity disorder (ADHD) (APA, 2025a).

ADHD is not so much a mental disability as it is a management problem in the brain's executive functions (particularly inhibition and focus). When observing the behaviour of children with this condition in the classroom, they exhibit behavioural problems such as limited ability to concentrate, distractibility, difficulty listening to instructions, disorganisation, forgetfulness, motor restlessness, poor impulse control, excessive talking, inability to wait their turn, and difficulty following rules. These students are unable to pay attention to one or more stimuli at the same time, fidget constantly, remain standing when expected to sit, run around aimlessly in the classroom, are unable to complete a task, constantly interrupt others, and answer questions before they are finished (Özmen & Özmen, 2010).

When this behavioural pattern is examined, it becomes apparent that the root cause of the problem is not the child's "unwillingness" but rather the deficiency in the inhibition mechanism discussed earlier. This neurobiological "failure to apply the brakes" creates a dual structure that presents both risks and opportunities in science teaching processes.

Safety and Impulsivity: Science lessons are inherently stimulating but require strict adherence to rules. For a student with ADHD, the laboratory environment is full of difficult-to-manage impulses. For example, in an experiment involving acids, a student touching the material without waiting for safety instructions (motor impulsivity) could lead to serious injury or chemical burns. This is not "mischief" but the result of the brain's inhibitory mechanism failing to engage at that moment (DuPaul & Stoner, 2014).

Focus and Sustainability: Even in subjects that are actually extremely interesting and intriguing, such as astronomy or life in space, students with ADHD may lose focus during lessons. This should not be confused with a lack of interest. The problem is not a lack of interest; it is the inability to sustain attention on the same point for a long time. Even if the student likes the subject, the learning process is interrupted because their mind wanders to another stimulus (a bird flying past the window, a friend's pen, etc.) (Willcutt et al., 2005).

However, on the flip side, science lessons hold unique potential for students with ADHD. Research shows that the "learning by doing" model offered by science education aligns with the mobility and multi-sensory stimulation that these students need. Moving from the position of a passive listener to that of an active practitioner conducting experiments has the potential to significantly increase the attention span and participation of students with ADHD in science classes compared to other subjects (DuPaul & Stoner, 2014).

Autism Spectrum Disorder (ASD)

While learning difficulties and ADHD often involve cognitive capacity being present but performance-limiting processes being at the forefront, autism spectrum disorder (ASD) involves a more comprehensive profile of differences in social communication, behavioural patterns, and sensory processing dimensions (APA, 2025b). ASD is a neurodevelopmental disorder characterised by persistent difficulties in social communication and interaction, restricted/repetitive behaviour patterns and interests, and often unusual responses to sensory input (APA, 2025b). The emphasis on "hyper- or hyporeactivity to sensory input" in the DSM criteria is therefore important (Grzadzinski et al., 2013; Wiggins et al., 2019).

This definition may create a "double-edged" framework in terms of science education. On the one hand, some profiles of individuals with ASD may exhibit strengths such as detail-orientedness, systematic thinking, learning more comfortably with structured frameworks, and intense focus on specific areas of interest. Therefore, the structured, causal, and predictable nature of science lessons can create a secure learning environment with appropriate adjustments (Craig et al., 2016). However, popular discourses attributing ASD diagnoses to historical scientists raise issues of retrospective diagnosis in terms of the history and methodology of science; such claims should be used cautiously in educational justifications (James, 2003; Weinstein, 2023).

On the other hand, limitations in executive functions can complicate science teaching. The literature on executive function difficulties in ASD indicates that difficulties may be common, particularly in areas such as planning and cognitive flexibility (Craig et al., 2016; Happé et al., 2006). This situation may manifest in science education in the following areas:

Abstract concepts and the use of metaphors/analogies: Meta-analytic findings indicate that individuals with ASD may experience difficulties in understanding metaphors, similes, and other types of figurative language. Therefore, the use of analogy in science education should be structured with more concrete support according to the student profile (Kalandadze et al., 2018; Vulchanova & Vulchanov, 2022).

Cognitive flexibility and "insistence on sameness": When an experiment yields unexpected results or requires trying alternative solutions, it can cause anxiety and resistance because it requires flexibility; this may be related to the limited flexibility seen in ASD (Craig et al., 2016; Happé et al., 2006).

Sensory sensitivities: Odours, sounds, and tactile stimuli in the laboratory environment may trigger avoidance rather than learning for students with sensory hypersensitivity. Sensory reactivity is explicitly highlighted in the OSB diagnostic criteria and clinical descriptions (Wiggins et al., 2019).

Consequently, the success of a student with ASD in science education depends on the teacher recognising this distinct cognitive/sensory profile and adapting instruction to be concrete, predictable, structured, and sensory balanced (Craig et al., 2016; UNESCO, 2017).

Executive Functions

Executive functions are a set of higher-level cognitive processes that enable individuals to organize their thoughts and behaviours in a goal-directed manner. These functions are defined as a "cognitive management system" that enables individuals to plan what to do, when to do it, how to do it, and with which strategy, to monitor the process, and to modify it when necessary (Diamond, 2013; Miyake et al., 2000). Executive functions are directly related not only to the content of learning but also to how learning is managed. In an educational context, executive functions are considered a strong predictor of many outcomes, such as academic achievement, self-regulation, problem solving, and social adjustment (Best et al., 2011). The role of executive functions becomes even more prominent in constructivist learning environments, where students are expected to actively process information and manage the learning process (Zimmerman, 2000).

Basic Components of Executive Functions

There is consensus in the literature that executive functions consist of a multi-component structure. According to the most widely accepted classification, executive functions consist of working memory, inhibition, cognitive flexibility, and planning/self-regulation components (Diamond, 2013; Miyake et al., 2000).

Working memory enables the temporary storage and simultaneous processing of information during learning. The learner's ability to follow instructions, compare information, and establish cause-and-effect relationships depends on this capacity (Baddeley, 2000). Working memory plays a critical role, particularly in science learning processes involving multi-step tasks.

Inhibition (impulse control) refers to an individual's ability to suppress automatic or inappropriate responses and direct their attention towards a goal. This skill is an indispensable component of learning environments in terms of sustaining attention, following rules, and demonstrating safe behaviour (Barkley, 1997; Diamond, 2013).

Cognitive flexibility refers to an individual's ability to adapt to changing circumstances, evaluate different perspectives, and generate alternative solutions. The processes inherent in scientific thinking—formulating hypotheses, falsifying them, and developing new explanations—directly rely on cognitive flexibility (Kuhn, 2010).

Planning and self-regulation involve an individual setting a goal, sequencing the steps necessary to achieve that goal, monitoring the process, and changing strategy when necessary. The design, execution, and evaluation of science experiments are concrete manifestations of these skills (Zimmerman, 2000).

Executive Functions and Children with Special Needs

Academic difficulties in children with special needs often stem not from a lack of knowledge but from limitations in the processes of processing and managing that knowledge. Difficulties in executive functions form a common ground in neurodevelopmental differences such as Specific Learning Difficulties, Attention Deficit Hyperactivity Disorder (ADHD) and autism spectrum disorder (ASD) (Willcutt et al., 2005).

In students with specific learning difficulties, limitations in working memory and planning processes, in particular, make it difficult to translate academic potential into performance (Swanson & Kim, 2007). In ADHD, inhibition and attention regulation difficulties are at the forefront, which can pose risks in terms of safety and sustainable participation in learning environments (Barkley, 1997). Cognitive flexibility limitations and sensory regulation difficulties, frequently seen in ASD, can make generalising learning and adapting to new situations difficult (Happé et al., 2006).

In this context, executive functions are considered a critical lever in the learning processes of children with special needs. Direct support for these functions is not a "prerequisite" independent of academic content; it is an integral part of learning itself.

The Importance of Executive Functions in the Context of Science Education

Science education is a learning domain in which executive functions are naturally activated through scientific process skills such as observation, experimentation, hypothesis formation, and problem solving. What is expected of students in science lessons is not to memorise information, but to think, question, and reconstruct it using that information.

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In this respect, science education provides a context in which executive functions are transformed from abstract cognitive processes into concrete and functional skills. For students with special needs in particular, science teaching creates a strategic learning environment in terms of supporting, strengthening and generalising executive functions.

Consequently, executive functions form the invisible but decisive foundation of science learning processes for children with special needs. An educational approach centred on these functions supports not only academic achievement but also the student's independence, self-regulation, and lifelong learning capacity.

Educational Interventions and Strategies

When educational needs and developmental stages are assessed holistically, the decisive role of executive skills in academic and social success becomes clear. However, the difficulties experienced by students with special needs in these critical cognitive processes (planning, inhibition, flexibility, etc.) compared to their peers bring with them a legitimate concern that must be managed not only for the student themselves, but also for families and educators (Diamond, 2013). Alleviating this concern and maximising potential depends not on expecting the student to conform to the system, but rather on adapting the teaching system and methods to the student's cognitive needs. At this very point, science education, thanks to the concrete materials, visualisations and experimental processes inherent in its nature, is one of the most suitable disciplines for supporting weak executive functions (scaffolding). A properly designed strategy in science lessons has the power to rehabilitate not only the student's academic success but also their problem-solving skills in life.

In line with this, the following section of the study will examine, in a multidimensional manner, both the classroom adaptation processes of inclusion/ integration students attending mainstream classes and the teaching activities carried out in special education classes, focusing on science education and executive skills, using low-cost but high-impact strategies.

Teaching Programme Intensity and Cognitive Load Management

One of the most fundamental pedagogical debates in education concerns the extent to which the density of information in educational programmes aligns with students' cognitive development levels. As the question "How much information?" gives way to "How much depth?", a fundamental paradigm shift is also taking place in our country's education policies. Indeed, when examining the Turkey Century Education Model, this vision is articulated as follows (MEB, 2024):

"*Teaching programmes have been prepared with a simple and in-depth approach focused on skills and values, rather than detailed and academic piles of information, in line with students' developmental levels. In this context, the content density in the programmes has been diluted to enable students to understand the subjects more deeply and establish interdisciplinary relationships.*"

This simplification approach is strongly grounded in Cognitive Load Theory in the literature. The theory's pioneer, Sweller (1988), "presented a teaching design framework that aims to efficiently use the human mind's information processing capacity during learning" (Özçınar & Bayındır, 2025). According to this framework, the student's working memory has a limited capacity, and when this capacity is filled with unnecessary details or poorly designed materials (unnecessary cognitive load), actual learning cannot take place.

When it comes to students with special needs, this "load management" is a vital necessity. This is because the cognitive bandwidth of these students fills up more quickly due to limitations in their executive functions. Therefore, science teaching in special education should be refined, free from unnecessary theoretical overload and rote learning (Diamond, 2013; Sweller et al., 2011). Science lessons, with their dense theory and abstract concepts, may appear to be a potential area of "cognitive overload," but when properly structured (through simplification and experiential learning), they become the most effective tool for alleviating this burden. The reflection of this strategic simplification on diagnostic groups is as follows (Barkley, 1997; Sweller, 1988):

ADHD and Impulse Control: Dense texts and complex instructions create "stimulus pollution" for a student with ADHD. A simplified, action-oriented science activity reduces this mental noise, allowing the student to focus their impulses on a specific goal (the outcome of the experiment).

Specific Learning Difficulties and Working Memory: Teaching that relies on books and dense texts causes a dyslexic student to expend their working memory solely on "reading." However, the visualisation and experimental processes in science education remove the text load, allowing the student to allocate their cognitive capacity directly to "understanding the concept."

Autism and Concretisation: For individuals with autism, abstract and metaphor-laden narratives are unnecessary burdens that strain the mental processor. Concrete science activities that are directly related to life, with reduced cognitive load, eliminate the complexity in these students' processes of making sense of the world.

Concretisation and Multi-Sensory Teaching

The greatest handicap of traditional classroom environments is that information is usually conveyed through theoretical and verbal channels, while students struggle to visualise (imagine) this information in their minds. This situation becomes even more critical when considered in the context of Piaget's Cognitive Development Theory. Science teaching at secondary school level in particular often involves concepts that require abstract thinking skills (atoms, forces, energy), while students especially those with special needs may still be in the concrete operational stage or require concrete support. This "cognitive gap" between the abstract expectations of the curriculum and the concrete needs of the student is one of the fundamental causes of learning difficulties (Eroğlu, 2023).

The shift towards a constructivist approach in 21st-century education and the widespread adoption of Multiple Intelligences Theory have necessitated a transition from "one-size-fits-all" teaching to "multisensory" teaching in order to bridge this gap. The aim now is to make abstract lesson content more concrete by enriching it with visual, auditory and tactile materials. The effectiveness of this approach is also supported by academic studies in the field of special education. For example, in a study conducted by Şafak et al. (2018) with students with visual impairment and autism spectrum disorder (ASD), it was found that the multisensory storytelling method increased the students' comprehension levels to an 83% success rate, concluding that multisensory teaching is quite effective in this group (Şafak et al., 2018).

So, how does concretisation and multisensory teaching, which is so effective in verbal skills, contribute to science lessons, where abstraction is most intense? A review of the international literature reveals that incorporating tactile (haptic) experiences into the process, in addition to visual and auditory stimuli in science education, facilitates the understanding of abstract science concepts and improves learning performance (Minogue & Jones, 2006). Researchers emphasise that this multisensory approach reduces students' cognitive load and strengthens the mental modelling of microscopic (cell, atom) or abstract processes in particular.

When combined with the "Cognitive Load" theory mentioned in the previous section, the picture becomes clear: For a student with special needs, simply "listening" or simply "reading" are abstract processes that quickly exhaust working memory. However, when the student touches the material, conducts the experiment themselves, or observes nature in an out-of-school environment, the information becomes concrete. This reduces cognitive load and allows executive skills (focusing, retaining in memory) to work more efficiently. Therefore, science teaching should transcend classroom walls and textbooks, transforming into a material-supported, multi-sensory discovery process.

Laboratory Arrangements and Safety

Science education takes place across a broad spectrum, ranging from theoretical classroom instruction to laboratory applications, and from school gardens to out-of-school learning environments such as planetariums and science centres. While the diversity of these environments enriches learning, it also places critical responsibilities on the teacher as an 'environmental organiser' in terms of management and safety.

When it comes to individuals with special needs, the physical layout of the environment is not only a matter of safety, but also serves as a "structural scaffold" that externally supports the student's weak executive skills. A chaotic or poorly organised environment can pose serious risks by straining the students already limited cognitive capacity. We can list these risks and the pedagogical measures that need to be taken for specific diagnostic groups as follows:

Specific Learning Difficulties (SLD) and Information Processing Security

The fundamental risk for students with dyslexia (reading difficulties), dyscalculia (mathematical difficulties) or dysgraphia (writing difficulties) is the incorrect processing of written and numerical data in the environment.

Risk (Incorrect Matching): A dyslexic student may confuse similar labels on chemical bottles (e.g., HNO3 and H2O) or forget the warning "Caution: Corrosive" at the beginning of the text while reading safety instructions because their working memory is full. A student with dyscalculia may struggle to grasp the difference between 5 ml and 50 ml, leading them to prepare dangerous mixtures in incorrect proportions. This is not carelessness, but a neurological difference in the process of interpreting symbols.

Teacher Strategy (Visualisation): The principle of "Universal Design" should be applied in the laboratory environment. Chemical bottles should be labelled not only with text but also with pictograms (visual symbols) representing their contents. Safety guidelines should be presented using infographics rather than long texts; critical levels on measuring instruments should be marked with coloured bands to reduce the student's "reading load".

Attention Deficit Hyperactivity Disorder (ADHD) and Impulse Control

For students with ADHD, the laboratory environment is like a playground filled with impulses that are difficult to control.

Risk (Motor Impulsivity): Every extra piece of equipment on the table is a stimulus waiting to be touched. The student's inability to control their motor impulses (lack of inhibition) and sudden interaction with hazardous chemicals or impatience to start the experiment before the instructions are finished can lead to serious injury.

Teacher Strategy (Stimulus Reduction): The teacher should organise laboratory tables according to the "just-in-time production" principle. Only the materials to be used in the current experiment should be on the table and all unnecessary equipment should be removed from the student's field of vision. This strategy reduces the load on the student's inhibition mechanism.

Autism Spectrum Disorder (ASD) and Sensory Regulation

In individuals with ASD, the primary issue is often sensory sensitivities rather than impulsivity.

Risk (Sensory Overload): The pungent chemical odours in laboratories, the flickering of fluorescent lights, or the high-pitched sounds emitted by glass materials can cause sensory overload in these students. When a student's sensory comfort is disrupted, their stress levels increase, their ability to focus diminishes, and they may experience a crisis by shutting themselves off from the outside world.

Teacher Strategy (Sensory Comfort): The environment should be well ventilated, natural light should be used where possible, and measures should be taken to reduce noise. In addition, introducing the student to the laboratory before the lesson (preparation) and explaining what they will encounter helps them manage anxiety caused by uncertainty.

In conclusion, environments for science teaching in special education should be designed according to the principle of "Reduced Stimuli, Increased Safety". These arrangements support the student's executive functions, ensuring an accident-free and productive learning experience.

Conclusion and Recommendations

The primary motivation behind this study is to go beyond discriminatory practices in education and advocate for the principle of "science for all." The right to education, guaranteed in Article 26 of the Universal Declaration of Human Rights, and the prohibition of discrimination, emphasised in Article 2, define the access of individuals with special needs to education not as a privilege but as a fundamental human right guaranteed under international law. However, equal opportunity is only possible through quality educational processes that enable students to realise their individual potential, not just through access to school.

As examined throughout this study, 21st-century skills (4Cs: Communication, Collaboration, Critical Thinking, Creativity) are built upon the brain's management mechanism, known as executive functions, rather than being independent competencies. The executive functions addressed in this study are central to the science learning processes and academic participation of students with special needs. Particularly in students diagnosed with Specific Learning Difficulties (SLD), attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD), the fundamental cause of academic failure is often not intellectual disability, but neurobiological differences in these executive functions. The impulsivity of a student with ADHD in the laboratory, the memory limitations of a student with SLD in processing written instructions, and the difficulty of a student with ASD in understanding abstract concepts are among the fundamental obstacles that cannot be overcome with traditional teaching methods.

It is precisely at this point that Science Education comes to the fore as a strategic rehabilitation tool. The nature of science, which involves learning by doing, concretisation, and a systematic structure based on cause-and-effect relationships, offers unique opportunities to strengthen weak executive skills. Multisensory materials reduce the load on working memory, structured laboratory environments support impulse control, while nature observations enhance cognitive flexibility.

Consequently, science teaching in special education is not merely the transmission of an academic curriculum, but a process of restructuring the student's problem-solving skills (executive functions) in relation to life. The success of this process does not depend on physical resources or an abundance of materials; the key determining factor is the teacher's awareness and transformative role. The most powerful key to transforming the potential of these special children into performance is for teachers to ask "how can we do it?" when the student says "I can't" and to adapt the environment, method and expectations to the student's cognitive needs (Cognitive Load Management). In this context, it is recommended that teachers approach the science learning processes of students with special needs not only in terms of academic gains but as a holistic process that supports the development of executive functions.

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SECTION 4.
STUDENT PSYCHOLOGY AND ACADEMIC ACHIEVEMENT

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TEST ANXIETY AND UNIVERSITY ENTRANCE EXAM

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INTRODUCTION

Throughout human history, the development of individuals through education has been seen as important, and the value placed on education has also grown in importance over time. In today's world, attending university is seen as the path to a secure job and future, and this situation has a negative psychological effect on young people (Ay, 2018). For students, exams are a series of assessment processes that begin in elementary school and continue throughout their education, preparing them for the university entrance exam, which is seen as the most important exam they will take in their lives (Erdayı, 2009). The Turkish education system is focused on academic achievement, and getting students into a good university has become one of the most important goals of the education system in our country (Yıldırım, 2006). Success has become the most important concept in the Turkish education system; parents and teachers have also begun to focus all their efforts on getting students high marks on exams (Ergene & Yıldırım, 2003).

Individuals preparing for university entrance exams are generally adolescents, who are trying to establish themselves in society, resolve their identity confusion, and strive to achieve their personal goals, such as passing exams. Coping with the changes experienced during adolescence, completing developmental tasks, striving to find and establish an identity, and, in addition to these, exam stress and anxiety about the future have a negative impact on adolescents' psychological well-being (Erdayı, 2009). The university preparation process is an exhausting and challenging process for students, and during this process, students pay many prices and experience various problems (Ergene & Yıldırım, 2003). For many adolescents, preparing for university entrance exams is an exhausting and arduous process that causes various psychological problems (Güler & Çakır, 2013). During the university preparation process, students experience many daily problems such as lessons, transportation, noise, personal problems, friends, and family. They should be supported by their families, friends, and teachers during this difficult period, and students should also maintain healthy relationships with each other. However, it is understood that some students do not receive sufficient support from their environment (Yıldırım, 1991).

Anxiety

It can be said that the information age, advanced technology, the fast pace of life, and robotization, along with many other factors such as people's decreasing tolerance and understanding levels, have led people to adopt an anxious lifestyle (Tuncer & Voltan-Acar, 2006). Many studies have been conducted on the concept of anxiety, and this concept has been defined in different ways. Some definitions of the concept of anxiety are as follows: According to the Turkish Language Association (TDK), anxiety means worry and concern. Anxiety is a state of arousal that arises in response to changes experienced by a person when faced with a stimulus (Cüceloğlu, 2005). It is a universal and normal emotion that individuals display in response to psychological events occurring in their environment (Duman, 2008). Anxiety is a signal that warns of danger and risk (Şahan, 2019).

The concept of anxiety is generally a response that arises when individuals feel insecure, expressing feelings such as hopelessness, fear, and pessimism, thereby negatively affecting individuals' lives and causing them to fail (Hill & Sarason, 1966). It should be noted that anxiety is not entirely a bad thing; a sufficient level of anxiety is necessary to achieve success in any field. Therefore, the correct approach is not to eliminate anxiety completely, but to maintain it at a certain level and benefit from it (Yolcu, 2015). Anxiety allows us to recognize potential threats and plan accordingly. In this sense, anxiety is adaptive and enables us to take precautions against possible problems before they occur (DSM-5).

Although the concept of anxiety is used synonymously with the concept of fear in everyday life, they are concepts with different meanings. The fact that both concepts have effects such as increasing heart rate, causing muscle tension, and creating a tendency to flee leads to the mistake of using them interchangeably (Özer, 2002). According to the DSM-5, anxiety is worrying about an expected problem, while fear is a response to a present danger. The causes of anxiety can include uncertainty, negative thoughts, conflict, personality, genetic makeup, family factors, environment, time management, past experiences, and physical causes (Şahan, 2019).

Types of anxiety

Spielberg (1972) examined anxiety under two headings: "state anxiety" and "trait anxiety" (Öner & LeCompte, 1998). State anxiety is the temporary and normal feeling of nervousness and fear that every person experiences in dangerous situations (Başol & Zabun, 2014). State anxiety increases in environ-

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ments where stress is high, and decreases when stress decreases or disappears completely (Yolcu, 2015). Accordingly, test anxiety is a state anxiety (Başol & Zabun, 2014). Trait anxiety is an individual's tendency to perceive situations as stressful and their predisposition to anxiety. Individuals with high levels of persistent anxiety exhibit characteristics such as being easily hurt, offended, or pessimistic (Öner & LeCompte, 1998).

Test anxiety

According to Spielberger, test anxiety is a condition that causes restlessness, tension, and unpleasant feelings in individuals and ultimately prevents them from performing to their true potential (cited in Yıldız, 2007). Anxiety is an emotion that disturbs individuals and can have a significant impact on their lives, and it is frequently observed in school environments (Hill and Sarason, 1996). Test anxiety is a type of anxiety that is more common in children and adolescents and begins before the test, negatively affecting the individual's performance on the test (Yavuz & Akagündüz, 2004). Test anxiety is a problem that lowers students' academic achievement, prevents them from realizing their potential, causes some students to take a break from their education, and seriously affects individuals' vital and professional decisions (Çabuk et al., 2015). Test anxiety is a phenomenon that hinders performance and learning in educational settings (Korkut-Owen et al., 2013).

Test anxiety is a condition that often develops during childhood and can increase in intensity in later years (Erözkan, 2004). Individuals with high levels of test anxiety may feel threatened when faced with evaluation. This can cause them to develop negative feelings about themselves and lead to a loss of concentration. Furthermore, individuals with test anxiety may also fail in areas such as reading questions correctly, answering correctly, and expressing themselves properly when speaking (Ergene & Yıldırım, 2003). Exams are a stressful situation for students, and the level of anxiety experienced can vary from student to student (Korkut-Owen et al., 2013). Exam anxiety is a condition that occurs during certain periods, but it can also occur intermittently during exam periods and become a constant state (Şahan, 2019). Exam anxiety can be seen not only in people with high levels of general anxiety but also in people who have never experienced anxiety before (Bilir, 2019).

Causes of test anxiety

There can be various causes of test anxiety. Many studies have been conducted on test anxiety, and according to these studies, the factors causing test anxiety can be grouped into familial factors, personal factors, educational policies, and school-related factors. One of the most important causes of test anxiety is peer pressure. High expectations from the environment and the anxiety of being able to keep up with time-limited exams are major factors that cause test anxiety to increase in individuals (Korkut-Owen et al., 2013). In addition, students' high personal expectations, some students setting their goals too high, unrealistic expectations and dreams, and perfectionism lead to increased test anxiety (Arslan, 2015). The reason why individuals with learning disabilities experience intense test anxiety is due to inadequacies in the test preparation process (Duman, 2008). In an assessment situation, if an individual does not have sufficient confidence in their ability, thinks they have not done their best, or, in short, feels unprepared, they experience discomfort and anxiety. Alternatively, if they are well prepared for the exam and believe they will perform well in the assessment, they will experience positive emotions (McDonald, 2001). Starting the exam preparation process late, not covering all the topics, not being able to review the topics as desired, and unplanned and unprogrammed study habits are also important causes of anxiety for students who feel they are not sufficiently prepared for the exam (Arslan, 2015). In such cases, students may become excited and panic because they cannot use what they know appropriately during the exam, causing their attention to wander, and they may cite exam anxiety as the reason for their failure (Yolcu, 2015).

Students' negative thoughts about exams also cause test anxiety. Negative experiences cause students to develop feelings of inadequacy and learned helplessness regarding exams (Duman, 2008). One factor that significantly affects exam anxiety is thinking errors. The thinking errors that cause exam anxiety are as follows (Türkçapar, 2018):

- Overgeneralization: drawing a general conclusion from a single negative event. "My math exam went badly, so all my exams will go badly." "I failed the exam. My dad will take me out of school."

- Labeling: Making negative statements about oneself.

- Filtering: Seeing only the negative aspects of events. "I got 4 questions wrong out of 20 on the Turkish test. I can never succeed."

- Disqualifying the Positive: Not accepting or dismissing positive aspects related to the issue. "I got a high grade on the exam, but I'm not a successful student; the exam was just easy."

- Personalization: The individual thinks there is a problem with them and directs the problems towards themselves.

- Catastrophizing: Constantly imagining disaster scenarios.

- Using mandatory sentences: This occurs when the individual believes they must do everything that needs to be done. They use words formed with mandatory expressions such as "should" and "must." "I must not make mistakes." "I must get a high score on the exam."

- Fortune telling: The individual makes negative predictions about future events and believes that things will not go well. "I know I will fail the exam."

Another factor that causes students to experience test anxiety is negative test conditions. Negative test conditions, such as the time factor and inability to use time effectively, cause test anxiety to increase (Arslan, 2015). The increasing importance attached to exams in the Turkish education system is a significant factor that increases exam anxiety (Arslan, 2015). In addition, teachers' demeaning and belittling attitudes and behaviors can also cause exam anxiety in students (Korkut-Owen et al., 2013).

One of the most important factors in the intensity of test anxiety is undoubtedly family attitudes. Every parent's attitude towards their children can be different. Some parents can be controlling, some can be doting, and some can be indifferent (Kurt, 2016). High parental expectations, parental indifference, inconsistent parental behavior, overly critical attitudes toward the child, and parents who are actually anxious themselves but reflect this onto their children are behaviors that further increase their children's test anxiety levels (Yavuzer, 2000). Students' gender and personality structures also affect their test anxiety levels. Individuals with competitive, assertive, perfectionist, and controlling personalities also have a high tendency toward anxiety (Başoğlu, 2007). In his research, Kurt (2016) concluded that individuals with high general anxiety levels also have high test anxiety levels.

Test anxiety is a condition that is more common during childhood and adolescence. Environmental factors such as discipline at home, parental attitudes, authoritarian school management, negative teacher criticism, passing grades, and punishments are situations that increase test anxiety in individuals (Öner, 1989). Factors such as gender, family socioeconomic status, number of siblings, academic achievement level, and parents' occupation contribute to the development of anxiety in childhood (Erözkan, 2011); while parental attitudes, school success, friendships, and exams are influential in adolescence (Başol and Zabun, 2014).

Symptoms of test anxiety

When experiencing excessive anxiety, individuals release high levels of adrenaline, which prevents them from transferring what they have learned and causes various reactions in the body (Başoğlu, 2007). Test anxiety manifests itself in individuals under four main headings: physical, mental, emotional, and behavioral (Başoğlu, 2007; Duman, 2008; Erözkan, 2011; Şahan, 2019; Tekbaş, 2009; Yolcu, 2015).

Mental symptoms: Hypervigilance, excessive self-monitoring, forgetfulness, inability to concentrate, inability to read and understand exam questions and written material, difficulty recalling learned information, negative beliefs and thoughts, and inability to follow instructions are the main mental symptoms of test anxiety.

Physiological symptoms: Increased heart rate, increased breathing rate, tension, excessive sweating, excessive shivering, headache and dizziness, facial flushing, diarrhea, vomiting, nail biting, body cramps, fainting, nausea, and chest tightness are the main physiological symptoms of test anxiety.

Emotional/psychological symptoms: Tense mood, excessive nervousness, pessimism, excessive fear of making mistakes and forgetting what one knows, panic, insecurity, general unhappiness, freezing up, helplessness, developing fears that were not there before, becoming insensitive to positive developments, and being constantly on alert are the main emotional and psychological symptoms of test anxiety.

Behavioral symptoms: Escape and avoidance behavior (stopping studying, leaving the exam halfway through), procrastination, finding excuses not to go to school, anger outbursts, inability to read or write, uncontrolled behavior, excessive restlessness, violence towards oneself or others, forgetfulness, impatience are the main behavioral symptoms of exam anxiety.

Effects of test anxiety

It is believed that the anxiety experienced by students attending school towards exams reflects on their success and perhaps their entire lives (Ocak & Yurtseven, 2016). The complex situations experienced by individuals make it difficult for them to make decisions, leading to stress (Avşaroğlu & Üre, 2007). It has been observed that students preparing for university and high school exams experience various emotional problems and that these students seek help from the Guidance Service at their schools or, in some cases, from psychologists and psychiatrists (Yıldırım, 2006). It is thought that the anxiety experienced by students attending school regarding exams reflects on their success and perhaps even their entire lives (Ocak and Yurtseven, 2016).

Moderate anxiety has been found to be beneficial for individuals in terms of starting work and completing tasks (Başoğlu, 2007). A certain level of exam anxiety can produce positive results; a sufficient amount of anxiety is good for students. If anxiety is at an adequate level, it can lead to positive outcomes for students, such as exerting more effort, taking precautions against difficulties, seeking support, learning how to manage test anxiety, and establishing reliable relationships with their environment (Şahan, 2019). Excessive test anxiety causes students to misread or misunderstand questions during the exam, leading to failure (Kurt, 2016). Test anxiety affects cognitive structure, preventing individuals from using their existing potential and leading to a decline in their success (Arslan, 2015). Intense anxiety experienced during the exam process can cause serious damage to the student's mental health, and symptoms such as hopelessness, unhappiness, anger, and nightmares may be observed in the individual. These negative feelings may disappear after the exam, but they may also continue for months or even years (Özkeskin Uluç, 2018).

In general, a certain amount of exam anxiety can lead to positive outcomes such as increased motivation, the ability to manage anxiety, and greater effort; however, high levels of exam anxiety can lead to negative effects such as difficulty understanding questions, difficulty organizing thoughts, leaving questions unanswered, damage to social relationships with others, failure in the exam, and difficulty recalling concepts and previously learned information, leading to lifelong test anxiety (Şahan, 2019).

Test anxiety and university entrance exams

In our country, individuals live in a competitive environment starting from the pre-school period, through elementary school, middle school, high school, university, and even throughout their lives. Young people preparing for university exams are expected to achieve high scores on these exams and be placed in attractive departments, and this situation causes various psychological problems in young people preparing for university exams (Yolcu, 2015). The university student selection and placement system has been one of the most debated issues in the Turkish education system for years. The most fundamental problem experienced within this system is exam anxiety. The majority of students preparing for the university entrance exam state that the most common obstacle they face while preparing for the exam is exam anxiety (Köse et al., 2018). This anxiety stems from the fact that individuals' decisions about their future are tied solely to an exam (Kutlu, 2001).

The exam anxiety experienced by young people preparing for university entrance exams is a state of that arises from the young person's inability to prove themselves, failure, learned helplessness, and comparison with their peers (Kutlu, 2001; Yolcu, 2015). The majority of students preparing for university entrance exams state that the most common obstacle they face while preparing for the exam is exam anxiety (Köse et al., 2018). Because the only way to enter university is tied to a single exam, students worry about possible mishaps, illnesses, or sad events they may experience on exam day (Kutlu, 2001). According to research conducted by the MEF Guidance and Research Service, the anxiety levels of students preparing for university entrance exams are higher than those of patients waiting for surgery (Cited in Erözkan, 2004).

It is considered normal for every student preparing for the university entrance exam to experience some degree of anxiety during this important exam, where they believe they will prove themselves and demonstrate their success (Boztepe, 2016). Exam anxiety, which begins during the university preparation process, is also seen in different forms during university studies and afterwards. The desire to succeed and anxiety about the future create tension in individuals and push students to be competitive and combative (Erözkan, 2011). University entrance exams, which are considered much more important than regular school exams, become a life goal for students, and failure in these exams can lead to serious depression and self-harm (Boztepe, 2016). During the preparation process for university entrance exams, which is a highly challenging and competitive process, some students experience emotional problems, and it has been observed that these students seek help from Guidance Services or psychologists and psychiatrists (Ergene & Yıldırım; 2003). Guidance counselors in schools should undertake various activities to balance the exam anxiety experienced by students and refer students experiencing severe anxiety to the necessary specialists and therapists.

Methods for coping with exam anxiety

Individuals experiencing anxiety develop various defense mechanisms to overcome their anxiety without being aware of it. However, these are unconscious coping methods (Kurt, 2016). Test anxiety is the worry and unpleasant feelings that arise when individuals feel they are being evaluated through various tests during their learning process. It is important to use effective coping strategies to deal with these situations (Erözkan, 2011).

To cope with test anxiety, individuals need to be physically comfortable. Regular sleep and regular nutrition are very important factors in this regard. Sleep and nutrition patterns support students physically (Yolcu, 2015). Students need to set their bedtime and wake-up times well to get enough sleep. In addition, students who eat breakfast in the morning will have clearer minds, making it easier for them to cope with anxiety. Family support is very important for this. In addition, light exercise and walking will provide physical relaxation and mental relaxation (Şahan, 2019). Considering that physical education and sports activities contribute to mental and psychological development as well as physical development, it is recommended that students participate in various sports activities (Özkeskin Uluç, 2018). Students experiencing exam anxiety can participate in sports activities suitable for them, such as soccer, basketball, archery, swimming, and gymnastics, to reduce their anxiety. In addition, in order to cope with exam anxiety and provide physical and emotional relaxation, students can take up hobbies that suit them.

Ergene and Yıldırım (2003) state that behavioral and cognitive approaches are effective in reducing exam anxiety. Among behavioral therapies, systematic desensitization and other behavioral techniques are seen to be effective, while among cognitive therapies, cognitive restructuring has the most significant effect. To cope with exam anxiety, students need to understand that the concept of success is variable and recognize the type of exam (Arslan, 2015). It would be beneficial for students to receive psychological support from an expert using cognitive behavioral techniques to transform their mental schemas and cope with their anxiety.

Individuals experiencing test anxiety should find ways to express their anxiety through methods other than talking, such as letters, diaries, stories, or pictures. The individual can work on their self-perception and incorrect thought patterns related to exams (Şahan, 2019). Teachers can reduce students' anxiety levels by enabling them to express their anxieties through various activities using expressive arts in class. In addition, students should be encouraged to develop writing and self-expression habits.

The anxiety experienced by the student feeds negative thoughts such as feeling ashamed in front of their family, friends, and teachers in the event of possible failure. In this case, the sensitivity of the parents is very important in coping with exam anxiety. It is very important for parents to talk to their children about their expectations regarding the exam and to express to them that the exam will not diminish their love or trust (Yolcu, 2015). The effective implementation of all the methods mentioned depends on family support.

One of the most important tasks for all of this to happen effectively falls to the experts. Experts should organize informative and supportive seminars for parents, teachers, and students, and especially convey to parents how much they affect their children's development process. With the support of the school counseling service, the stress and anxiety of the university exam on students and parents can be alleviated (Başol & Zabun, 2014). If parents and teachers help students with cognitive, affective, and behavioral strategies, students can effectively manage their exam anxiety (Akram Rana & Mahmood, 2010).

In his study titled Coping Strategies for Test Anxiety, Kondo (1997) investigated the strategies people develop to cope with test anxiety. He states that there are 79 basic tactics associated with 5 types of strategies to reduce test anxiety. These strategy types are: Positive thinking, relaxation, preparation, resignation, and concentration. Positive thinking is a cognitive process that involves attempting to change problematic thoughts related to the exam. Relaxation aims to reduce physical tension that arises emotionally. Preparation and concentration are both strategies developed to focus on behavioral components related to the exam. Research on resignation also shows that low-anxiety and high-anxiety individuals do not use resignation strategies very differently. Both high-anxiety and low-anxiety individuals resign for different reasons.

Conclusion

In conclusion, test anxiety is a common problem during the university exam preparation process and is influenced by factors such as parental expectations, pressure from the education system, personal perfectionism, negative thought patterns, and insufficient preparation for exams. Test anxiety has significant negative effects on learning and performance in physical (palpitations, sweating), cognitive (distraction, forgetfulness), emotional (hopelessness, panic), and behavioral (avoidance, procrastination) dimensions. In contrast, moderate anxiety can be motivating. Effective interventions include regulating sleep and nutrition, regular physical exercise, cognitive-behavioral therapy with thought restructuring, exam strategy training, strengthening guidance services, and increasing parental awareness. Information seminars at the school and family levels, the early development of coping skills, and the referral of high-risk students to professional support play an important role in reducing the negative effects of anxiety. Finally, educational policies that aim to reduce exam-centered competition and future empirical studies examining the long-term effectiveness of interventions will contribute to creating a healthier exam process culture at both the individual and societal levels.

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THE ROLE OF SELF-CONTROL IN COPING WITH STRESS AMONG ADOLESCENTS

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INTRODUCTION

Adolescence is a critical stage in which individuals undergo rapid biological and psychological changes, symbolizing the transition from childhood to adulthood. The rapid changes that occur during this period affect young people's relationships with their environment, leading to various sources of stress and difficulties in adaptation (Bencivenga and Elias, 2003). There are numerous factors that can contribute to stress in adolescents. The process of adapting to developmental changes itself can be a significant source of stress. A lack of effective coping strategies may further intensify these feelings. Therefore, it is crucial for adolescents to develop the coping skills they will need in adulthood during this stage of life (Basut, 2006; Byrne et al., 2007).

The responses of adolescents to stressful situations vary individually; some struggle to cope with difficulties, while others are able to navigate these processes more easily. These differences are influenced by the interaction between the stress coping skills developed by the individual and environmental support (Doğan, 2015). The ways in which adolescents cope with the difficulties they encounter are considered a coping process, and various strategies can be applied in this process. These strategies are not unique to adolescence; they are also among the important determinants of psychological health in the individual's later life (Barendregt et al., 2015; Ben-Zur, 2009; Chua et al., 2015; Clark, 2006; Collishaw et al., 2004; Latzer et al., 2015; Thomsen et al., 2015; Woodhead et al., 2014). A thorough examination of coping behaviors is crucial for understanding an individual's psychological well-being.

Self-control plays a crucial role in coping with stress. Individuals with low self-control are more likely to engage in dangerous, risky, and harmful behaviors, which can lead to a greater number of problems (Gottfredson & Hirschi, 1990). Moreover, self-control helps reduce both the negative situations individuals face and the emotional distress these situations may cause (Metin et al., 2017). Research also suggests that individuals with high self-control tend to be more adaptable, successful, and mentally resilient (Friese & Hofmann, 2009).

The stage of adolescence is a period that is characterized by numerous changes and innovations, but also by numerous problems. Adolescence, which is described as a stormy period, is also a time of crisis. It is very important to develop self-control skills in adolescents during this period. This is because the source of many problems experienced during this period is a lack of self-control (Şimşir Gökalp et al., 2022). It is known that adolescents with self-control skills are able to overcome crises more positively (Ronen et al., 2016). The concept of self-control focuses on an individual's capacity to regulate or modify their internal responses, as well as their ability to inhibit undesirable behavioral impulses and refrain from acting upon them (Tangney et al., 2004). In this context, the following section will explore adolescents' coping styles for managing stress and emphasize the significance of self-control in this process.

Stress and Coping Strategies

Stress is defined as a state of excessive arousal that occurs when an individual struggles to adapt to change, fights against it, and perceives the situation as a threat. This state manifests itself distinctly in both the body and the mind. Stress is a result of personality, environment, and interaction. An individual's perspective on their environment and their reactions also influence the emergence of stress (Lazarus & Folkman, 1984). Stress is created by the physical and emotional reactions that a person exhibits when there is a discrepancy between their experiences and the world they want to live in (Magnuson, 1990).

Stress manifests itself in various domains. Güçlü (2001) categorized these symptoms into four main areas: physical, social, emotional/spiritual, and mental. Physical symptoms that may arise as a result of exposure to stress include headaches, fatigue and loss of energy, irregular sleep, changes in eating habits, teeth grinding, increased susceptibility to infections, muscle and back pain, digestive problems (such as constipation or diarrhea), stomach ulcers, excessive sweating, high blood pressure, or even heart attacks (Aydın, 2017; Baltaş & Baltaş, 2016; Güçlü, 2001). In addition, behavioral responses to stress may involve suspicion toward others, fault-finding and criticism, blaming others, frequent arguments or withdrawal from communication, constant worry, canceling social plans, and reducing participation in social activities (Güçlü, 2001).

Emotional and psychological symptoms of stress may include frequent and sudden mood changes, decreased self-confidence, feelings of anxiety or suspicion, depressive behaviors or sudden crying spells, excessive sensitivity and vulnerability, irritability, a tense or hostile mood, difficulty controlling anger, emotional exhaustion, and occasional outbursts of rage (Baltaş & Baltaş, 2016; Güçlü, 2001). From a cognitive perspective, stress can impair thinking ability, leading to difficulties in decision-making, loss of concentration, decreased work performance, and a tendency to become lost in one's thoughts.

Coping Strategies

Stress can be categorized as either positive or negative. When stress has harmful effects on an individual and negatively influences their well-being, it is considered negative stress. Conversely, when it enhances resilience and fosters personal growth, it is referred to as positive stress. Thus, a certain level of stress in life can serve as a motivating force for individuals (Ceylan, 2006).

The concept of coping with stress can be defined as an individual's effort to manage stress-inducing factors that originate either internally or from the external environment. This process is dynamic and evolves over time (Deniz & Yılmaz, 2006; Ergin, 2018; Lüzumlu, 2013). There are two primary approaches to coping with stress: healthy coping and maladaptive (adverse) coping. While some individuals adopt positive behaviors and strategies when dealing with stress, others may display negative reactions. Healthy coping mechanisms contribute to well-being, whereas maladaptive coping tends to exacerbate distress. Ultimately, the coping path chosen varies from person to person (Topal, 2011).

The coping skills of individuals are largely developed during adolescence (Üzbe Atalay, 2016). Adolescents face stress resulting from physical, mental, sexual, social, and behavioral changes during their developmental period (Santrock, 2012). In the process of coping with these problems, adolescents' personal characteristics, approaches to problems, adaptive skills, ability to perceive alternatives, and thoughts related to themselves become important. The process of coping with stress involves approaching problems positively, considering alternatives, and evaluating the outcome (Baltaş & Baltaş, 2015).

There are two main approaches to coping with stress: problem-focused and emotion-focused coping strategies. In the problem-focused approach, the person addresses the source of stress directly and attempts to eliminate it. This process may require the individual to use various skills. In particular, acting in a self-controlled and planned manner by using problem-solving skills can help solve the problem more effectively. The emotion-focused coping strategy, on the other hand, is an approach aimed at alleviating the emotional effects of stress. Individuals who adopt this strategy try to manage their emotions related to stress rather than aiming to change the source of stress (Lazarus & Folkman, 1984). While controlling environmental factors is important in problem-focused coping, focusing on the individual's internal emotional factors is essential in emotion-focused coping (Altunkol, 2017).

Baltaş and Baltaş (2016) categorize coping strategies into three dimensions: physical, mental, and behavioral. The physical dimension includes factors such as maintaining healthy eating habits, engaging in regular exercise, and practicing relaxation techniques. The mental dimension involves the use of cognitive strategies and methods aimed at identifying and modifying irrational beliefs. The behavioral dimension focuses on effective time management and behavioral regulation to reduce stress and enhance overall well-being.

In sum, the following is a list of ways to cope with stress in the literature (Aydın & İmamoğlu, 2001; Ballı et al., 2016; Baltaş ve Baltaş, 2016):

- Breathing Exercises
- Meditation and Yoga
- Sleeping Regularly
- Relaxation Techniques
- Practicing Relaxation
- Effective Time Management
- Taking Breaks
- Learning to Enjoy Life
- Prayer and Worship
- Social Support
- Getting a Hobby
- Getting Professional Support
- Exercise

The Role of Self-Control in Coping

Self-control refers to an individual's ability to regulate their thoughts, emotions, behaviors, and impulses (Mehta, 2010; Tangney et al., 2004). It can be broadly defined as the act of exercising control over oneself. Individuals rely on self-control when they seek to modify their thoughts, emotions, or behaviors. The motivation behind self-control lies in maximizing one's long-term interests; thus, individuals demonstrate self-control by managing their desires and adhering to established rules and norms (Muraven & Baumeister, 2000).

Individuals with high self-control tend to value themselves more and are able to view life situations more positively, adapting more easily to changes. They are generally able to maintain positive thoughts about themselves across different circumstances and demonstrate a greater ability to understand others' perspectives, indicating stronger empathy skills. High self-control also contributes positively to various aspects of daily life. Such individuals are often more academically successful, as self-control enables them to organize their lives effectively. Moreover, self-control plays a crucial role in coping with depression, managing anger, preventing alcohol and substance addiction, reducing anxiety, and maintaining overall mental well-being (Tangney et al., 2004). Conversely, individuals with low self-control are more prone to act on their impulses and be influenced by them (Friese & Hofmann, 2009).

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Rosenbaum (1980) suggests that self-control skills can be learned, and that individuals differ in their levels of self-control due to variations in the intensity of what they have learned over time. Likewise, Muraven and Baumeister (2000) argue that self-control can be strengthened through practice.

Self-control is a skill that can both influence and be developed in daily life, playing a significant role in managing stress. This is because self-control involves an individual's ability to regulate their own behavior and emotional responses. High levels of self-control are essential for managing emotions such as anxiety and worry that arise from stressful situations (Günlü, 2021). By regulating thoughts and behaviors, self-control enables individuals to respond to stress in healthier and more adaptive ways (Hofmann et al., 2009; Sirois & Pychyl, 2016).

The literature indicates a reciprocal relationship between self-control and coping with stress. While self-control aids in managing stress, stress itself can undermine self-control (Şimşir Gökalp & Haktanir, 2024). The impact of stress on self-control is explained by the self-control strength model (Baumeister et al., 2000). According to this model, developed by Baumeister et al. (1994), exerting self-control in one situation consumes a finite amount of mental energy, reducing the effectiveness of self-control in subsequent situations (Baumeister, 2002). This reduction in the energy available for self-control is referred to as "ego depletion" (Forgas et al., 2009). When ego depletion occurs, an individual's self-control capacity diminishes, increasing the likelihood of impulsive behavior. Stress contributes to ego depletion, making it more challenging to regulate emotions and thoughts and to focus on problem-solving. As a result, when coping with stress, individuals may struggle with decision-making and become more susceptible to impulsive actions due to exhaustion (Baumeister, 2002).

Researchers suggest that self-control is a limited resource and may be sensitive to certain factors. For example, researchers suggest that stress weakens self-control capacity (Muraven et al., 1998) and that exposure to stressful situations during adolescence negatively affects the development of self-control (Zhang et al., 2019). Duckworth et al. (2013) reported that adverse life events and perceived stress impair self-control capacity in young people in early adolescence. Similarly, research conducted by Şimşir Gökalp and Haktanir (2024) revealed that perceived stress in adolescents is associated with a decreased capacity for self-control.

A review of the literature reveals that low self-control negatively affects coping with stress. For example, research conducted by Boals et al. (2011) reported that self-control negatively predicts avoidant coping. In a study by Lucke et al. (2024), it was found that self-control negatively predicted avoidance coping and positively predicted problem-focused coping. In another study conducted by Li et al. (2016), it was reported that self-control negatively affected negative coping and positively affected positive coping.

In summary, self-control is a skill that can serve as a protective factor in coping with stress. Having a high level of self-control during adolescence—a period marked by exposure to numerous stressors—can facilitate more effective coping. Therefore, interventions and studies focused on enhancing adolescents' self-control skills are likely to make a meaningful contribution to their ability to manage and overcome the challenges they face.

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