CURRENT CONCEPTS AND INNOVATIVE RESEARCH IN EDUCATIONAL SCIENCES

All Sciences Academy

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High School Students' Approaches to Learning and Learning Styles inTerms of School Type

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ABSTRACT

The aim of this study is to examine the relationship between high school students' approaches to learning and their learning styles, and to determine whether these variables differ according to school type. The study was designed as non-experimental quantitative research using a cross-sectional survey model. The study group consisted of 11th grade students attending science high schools, Anatolian high schools, social sciences high schools, imam hatip high schools and vocational high schools in Erzurum, Türkiye. Using convenience and stratified sampling, data were collected from 427 students; 39 forms were excluded as invalid and analyses were conducted on 388 students. Data were gathered through the Grasha–Reichmann Student Learning Styles Scale, the Study Process Questionnaire (Approaches to Learning Inventory) and a demographic information form prepared by the researcher. Descriptive statistics, Pearson correlation analysis, MANOVA and Chi-square tests were used for data analysis. The findings revealed that students predominantly adopted a surface approach to learning across all school types, and that there were no significant differences in deep and surface approaches according to school type. However, significant differences were found between school types in terms of independent and dependent learning styles; independent style was more prevalent among students in social sciences and science high schools, whereas dependent style was more common among Anatolian high school students. Moreover, the deep approach to learning was positively associated with independent, collaborative, participant and competitive learning styles, and negatively associated with the avoidant style. The surface approach was positively related only to the avoidant style. These results suggest that the exam-oriented structure of the education system strengthens students' tendency towards surface learning, and that secondary education curricula should be redesigned to foster deep learning and to better align instructional processes with students' dominant learning styles.

Keywords: *approaches to learning, learning styles, high school students, school type, quantitative research*

INTRODUCTION

In educational research, the learning process is described as a complex phenomenon with a multidimensional structure that cannot be easily defined (Alkhateeb & Bani-Milhem, 2020). In the literature, there are studies that attempt to explain this complex process through dimensions such as environment, curriculum, instructional materials, teaching methods and techniques, approaches to learning and learning styles. Within this body of work examining the learning process, it is observed that studies focusing on learners' approaches to learning have gained particular prominence

(Marougkas et al., 2023). As greater importance is attached to individuals' lifelong learning and development in a globalizing world, interest is shifting from research that merely investigates learning outcomes to studies that explore how individuals learn. Accordingly, in literature reviews, research focusing on the learning process rather than on the results or products of learning has come to the forefront (Duff et al., 2004; Hong et al., 2023). One of the key elements that has a direct influence on the learning process is approaches to learning (Erdal, 2024). Although approaches to learning appear as a theoretical construct, they in fact reflect the learner's internal motivation and orientation when attempting to learn a topic, namely whether the learner focuses on understanding or on memorization (Alkhateeb & Bani-Milhem, 2020; Çağdaş, 2023; Entwistle, 1991). In research on the learning process, Ference Marton was the first scholar to conceptualize approaches to learning (Ozan et al., 2017). According to Marton and Säljö (1976), if the products emerging at the end of the learning process differ from one another, then the learning process itself must also vary from person to person. Individuals prefer different approaches in order to analyse information and integrate what they have learned into their existing knowledge structures (Teoh & Yap, 2015). Academic studies on approaches to learning provide foundational knowledge that can significantly inform curriculum development efforts and national education policy in terms of supporting learners' development (Hong et al., 2023). During the development of education policies and curricula, data to be gathered from learners such as their approaches to learning and learning styles can make important contributions to the curriculum development process. Approaches to learning are crucial if students are to manage the learning process effectively and achieve the intended outcomes (Aktunç, 2023).

Approaches to Learning

Marton and Säljö (1976) conceptualized approaches to learning in two dimensions: deep and surface (Ozan et al., 2017). Although students may choose different approaches depending on the content to be learned, approaches to learning vary considerably according to the teaching–learning environment (Çağdaş, 2023). In his study, Ekinci (2009) reported that students' approaches to learning differ according to their intentions and that these can be divided into an intention to understand (deep approach) and an intention merely to pass the course (surface approach). Teoh and Yap (2015) argue that a surface approach to learning is characterized by rote memorization and arises from a desire to succeed with minimum effort, whereas a deep approach to learning, in contrast, involves a more detailed and meaningful engagement with the material. Reviews of the literature suggest that the surface approach represents a more short-term, transient form of learning, while deep and strategic approaches are associated with more long-term learning (Aktunç, 2023; Alkhateeb & Bani-Milhem, 2020; Arslan, 2017; Teoh & Yap, 2015). It has also been demonstrated in research that students who

adopt a deep approach to learning produce higher-quality learning outcomes at the end of the learning process (Trigwell et al., 1999).

Learning Styles

Another dimension of the learning process is learning styles, which refer to learners' differences in how they approach learning. For the educational process to be carried out effectively, individual differences such as learning styles need to be taken into account (Jilardidamavandi et al., 2011). The concept of learning styles was first introduced in 1960 by Rita and Kenneth Dunn and is treated as a set of biological and developmental behaviours that make the learning process more effective (Ataseven, 2014). The concept emerged as a result of research on individuals' differences in learning (Güven, 2004). According to Demir and Gürbüz (2020), learning styles express individuals' personal preferences and tendencies in the processes of acquiring, processing and recalling information. Each individual uses different methods and strategies in the learning process; these differences are referred to as learning styles. Learning styles are also defined as learners' preferences and priorities in the learning process (Zhou et al., 2024). Learning styles are important for enabling individuals to participate more effectively in educational processes and for adapting teaching methods to individual needs. In light of the literature reviewed, it would not be inaccurate to define learning styles as the individual abilities and preferences that learners draw upon during the learning process (Alan, 2017; Ataseven, 2014; Yadav & Shukla, 2021; Zhou et al., 2024).

Recognizing learners' learning styles in the educational process, and teachers' awareness of these styles, as well as organizing the learning environment and shaping the teaching process accordingly, increase the efficiency of learning (Farid & Abbasi, 2014; Türker & Bostancı, 2023). Considering that approaches to learning and learning styles vary according to different individual characteristics, differentiation strategies gain importance in instructional design. Differentiated teaching practices based on approaches to learning and learning styles offer students opportunities to access information more effectively and to make learning more permanent (Veznedaroğlu & Özgür, 2005). For example, the use of visual materials for students with a visual learning style, or the provision of hands-on experiences for individuals whose concrete experience style is dominant, are among the suggested strategies for creating effective learning environments. The convergence of students' learning styles with teachers' teaching styles on common ground makes the learning process more effective (Altun & Yazıcı, 2010).

As a result of various definitions and studies by different researchers, several learning style models have been proposed over the years, including those of Dunn and Dunn (1978), Kolb (1984), Gregorc (1985), Felder and

Silverman (1988), and Grasha and Reichmann (1996) (Ataseven, 2014; Cimermanova, 2018; Çağdaş, 2023; Kuzu, 2009; Türker & Bostancı, 2023). Identifying learning styles helps educators adapt their teaching methods to individual differences. In this way, students' learning processes become more efficient and their academic achievement increases. For instance, one study found that instruction structured according to preservice teachers' dominant learning styles had a positive effect on their academic achievement (Ergen & Gürbüz, 2019).

According to Grasha and Reichmann, learning styles are related to the extent to which individuals interact with their environment, their peers and the learning context during the learning process (Zencir, 2024). Grasha and Reichmann classified learning styles into three dimensions and six styles: participant–avoidant, collaborative–competitive and dependent–independent (Güven, 2004). Explanations of the categories in Grasha and Reichmann's classification of learning styles, as reported by various researchers, are presented in Figure 1 (Dağ & Karamustafaoğlu, 2023; Gayef et al., 2023; Güven, 2004; Zencir, 2024).

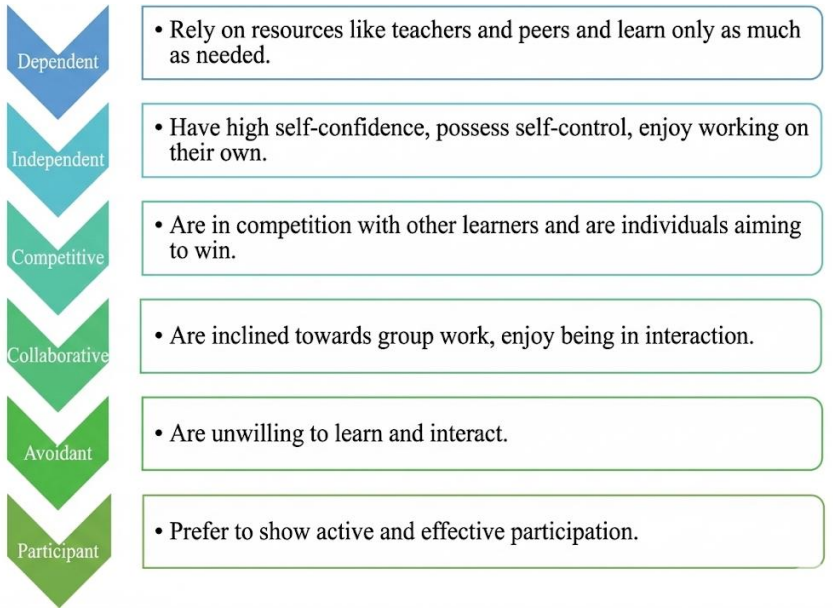

Figure 1: Grasha-Reichmann's Learning Styles

According to Sarıtaş and Süral (2010), the Grasha–Reichmann learning styles model is also directly related to students' approaches to learning. This relationship is one of the reasons why the Grasha–Reichmann Student Learning Styles Scale was chosen for the present study.

Learning Environment

Another key component of the learning process, and a concept that is related to both learning styles and approaches to learning, is the learning environment, that is, the school itself. In their study, Trigwell et al. (1999) demonstrated that students' approaches to learning are associated with their environment. In his research, Arslan (2017) also examined approaches to learning in terms of school type and reported significant differences. The present study aims to examine and reveal the differences in approaches to learning and learning styles according to school type, to contribute to the literature, and to offer recommendations to curriculum decision-makers and authorities.

In light of the literature review conducted, some studies on learning styles and approaches to learning are presented in Table 1.

Table 1: Related Researches

Author(s)	Study Group	Method	Variables	Findings
Ma (2024)	Instructional materials	Qualitative	Learning styles and Christian education	It was concluded that learning styles should be adopted and implemented in Christian education.
Nar (2024)	5th, 6th and 7th grade lower secondary school students	Quantitative	Academic achievement, attitude towards the course, gender, grade level, sociocultural environment and approaches to learning	Significant differences were found in students' academic achievement scores by grade level, parents' educational status and environment; in attitude scores by grade level; and in approach-to-learning scores by gender, grade level and environment. A positive correlation was identified between attitude mean scores, deep approach to learning and academic achievement.
Hong, Liu and Zhao (2023)	Preschool children	Quantitative	Preschool children's approaches to learning, gender, social skills, family income, family education level, school	It was concluded that all variables except being an only child produced significant differences in children's approaches to learning.

			type and only-child status	
Erdal (2024)	Vocational school students	Quantitative	Relationship between approaches to learning and academic achievement	A negative relationship was found between the surface approach to learning and achievement, while no relationship was found between the deep approach to learning and achievement.
Zencir (2024)	9th grade students	Quantitative	9th grade students' learning styles, academic achievement in English and motivation towards English	The independent learning style was found to be the highest and the competitive learning style the lowest. It was determined that students with an independent learning style had higher achievement scores, and a moderate positive relationship was found between motivation and academic achievement.
Çağdaş (2023)	11th grade students	Quantitative	11th grade students' approaches to learning mathematics, levels of motivation in mathematics, gender, parents' educational status and school type	Surface learning levels were found to be low and deep learning levels at a moderate level; deep learning levels and mathematics motivation levels were found to differ significantly by school type.
Marougkas, Troussas, Krouska and Sgouropoulos (2023)	Seventeen studies published in the last decade on approaches and methods to learning based on virtual reality technology	Qualitative	Virtual reality technology and approaches to learning	It was revealed that the deep approach to learning is the most frequently used approach together with VR technology.
Ozan, Karabacak, Kızıltas and Küçükoğlu (2017)	Preservice teachers (1st- and 4th-year students)	Quantitative	Learning styles and approaches to learning, gender, university,	The deep approach to learning was found to be high; approaches to learning differed significantly by department and gender.

			year of study and department	Learning styles did not differ by university, gender or year of study.
Gökalp (2013)	University students	Quantitative	Learning styles and academic achievement	As a result of activities administered to students according to their learning styles, a significant difference was found in their academic achievement.
Ozan, Köse and Gündoğdu (2012)	Preschool teaching and primary school teaching students	Quantitative	Gender, department and approaches to learning	A significant difference in the surface approach to learning was observed by gender, and it was found that male students were more likely to adopt a surface approach to learning.

In reviews of the literature on approaches to learning and learning styles, it has been observed that studies are predominantly conducted with preservice teachers at the higher education level, whereas fewer studies have been carried out at the high school level. In the relevant literature, approaches to learning are generally examined together with variables such as socioeconomic status, family background, age, gender, department, achievement, personality and attitudes towards the course, and no study has been found that relates approaches to learning to school type and learning styles at the high school level. In addition, an examination of the nationally implemented curricula shows that subject curricula do not vary according to school type (MEB, 2024). It is known that in different federal states of Germany, different curricula are implemented in line with diverse needs and demands (Doğan, 2020). Considering that the learning process becomes diversified through individual approaches to learning and learning styles, the present study may contribute to the literature by identifying the need for differentiated curricula for individuals with different learning styles and approaches to learning in different types of high schools.

Based on the studies reviewed in the literature, no research has been identified at the high school level that examines learning styles and approaches to learning according to school type. In today's context, where learner-centred and constructivist understandings of education place greater emphasis on research focusing on learners, it is thought that a study addressing these two variables together will contribute to the literature. The individualization of educational processes and the development of programmes that respond to students' diverse learning needs have become among the primary goals of education systems. Understanding students' approaches to learning and learning styles plays a critical role not only in

enhancing their academic achievement but also in increasing the effectiveness of teaching–learning processes. By revealing the relationship between high school students' approaches to learning and their learning styles, this study aims to provide the scientific basis needed for the design of curricula. Furthermore, if approaches to learning and learning styles are found to differ according to school type, the importance of developing differentiated curricula for different types of high schools will be underscored.

Although there are many studies in the literature on approaches to learning and learning styles, research that examines the relationship between these two variables in detail specifically for high school students and in terms of school type is limited. This study seeks to address this gap and to guide future research on both approaches to learning and learning styles.

The findings of the research may provide guidance to curriculum developers and education policy-makers in the process of curriculum development. In particular, if significant differences are identified by school type, it may be suggested that curricula implemented in high schools should be diversified. This is important for the wider dissemination of individualized education and for enabling students to participate more effectively in their learning processes.

The fact that each student has different approaches to learning and learning styles necessitates that curricula be structured in a way that takes individual differences into account. However, the limited number of studies in Türkiye that address high school students' approaches to learning and learning styles in a holistic manner indicates a need for further research in this area. In particular, examining the differences in students' learning processes across different types of high schools may support these school types with programmes designed in line with their educational goals. Therefore, the findings of this study are expected to make significant contributions to the education system, education policies and curricula.

The purpose of this study is to determine the relationship between high school students' approaches to learning and learning styles, to examine whether approaches to learning and learning styles differ according to school type, and to demonstrate to curriculum development authorities the importance of implementing different curricula for different types of high schools.

In line with this purpose, the study seeks to answer the following research questions:

- What are high school students' approaches to learning?
- What are high school students' learning styles?

- Is there a relationship between high school students' approaches to learning and their learning styles?
- Is there a significant difference in high school students' approaches to learning when examined in terms of school type?
- Is there a significant difference in high school students' learning styles when examined in terms of school type?

METHOD

Research Design

The purpose of this study was to reveal the relationship between high school students' learning approaches and learning styles, and to determine whether these variables differ according to the type of high school students attend. In line with the research purpose and sub-questions, a cross-sectional survey design—one of the non-experimental quantitative research methods—was adopted. The cross-sectional survey model is a design in which data are collected within a specific time period and is preferred to describe, analyze, and evaluate an existing situation in a study group as it is (Creswell, 2011). It is used to examine individuals' views, attitudes, approaches, and behaviors in relation to the specified variables (Christensen et al., 2014). The survey model not only presents cases, frequencies, or the distribution of characteristics within a particular sample, but can also be used to examine relationships among variables and causality (Fraenkel et al., 2012; McMillian & Schumacher, 2010).

Sample

The population of the study consisted of 11th-grade high school students in the province of Erzurum. According to statistics released to the public by the Ministry of National Education, the identified population includes a total of 9,692 students—4,924 male and 4,708 female (MEB, 2024). The main reason for selecting 11th-grade students is that, at this level, students choose academic tracks such as quantitative, verbal, and equally weighted (mixed) fields. It was assumed that students would be more purposeful and motivated in their learning approaches and styles after choosing a track, and thus would provide more accurate data during the research process. According to Edwin Locke's goal-setting theory, individuals carry out goal-directed actions with higher motivation (Aslan & Doğan, 2020). Therefore, it was aimed to obtain more accurate data from motivated and goal-oriented individuals. For a research population of approximately 10,000 students, the required sample size was calculated as 370 at a 95% confidence level (Christensen et al., 2014).

Sample selection was determined using an appropriate stratified method. The study group was determined in two stages: first through

convenience sampling and then through stratified sampling. Convenience sampling is a method that requires lower cost and provides ease to the researcher in terms of accessibility and time (Creswell, 2011). Stratified sampling, on the other hand, is a sampling method in which the population is divided into subgroups or strata based on certain characteristics, and a specific number of individuals are selected from each stratum. This method is used to ensure that different groups in the population are represented in the sample (Cohen et al., 2016; McMillian & Schumacher, 2010). To ensure data diversity, five strata were identified: science high schools, Anatolian high schools, social sciences high schools, imam hatip high schools, and vocational high schools; one school from each stratum was selected using convenience sampling. In total, 427 11th-grade students from these five strata participated in the study; however, 39 responses were considered invalid due to missing data and random marking. Demographic information regarding the study sample is presented in Table 2.

Table 2: Demographic Characteristics of the Sample

School	Female		Male		Total	
	N	%	N	%	N	%
SBL[4]	53	%60.9	34	%39.1	87	%20.4
AİHL[5]	52	%54.7	43	%45.3	95	%22.2
FL[6]	51	%45.5	61	%54.4	112	%26.2
AL[7]	55	%59.1	38	%40.9	93	%21.8
ML[8]	0	%0	40	%100	40	%9.4
Total	211	%49.4	216	%50.6	427	%100

No pressure was placed on the participants to complete the scales, and the data were collected entirely on a voluntary basis. Ethical approval and research permissions related to the study were obtained from the relevant institutions.

Data Collection Instruments

In this study, the Grasha–Reichmann Student Learning Styles Scale, adapted into Turkish by Sarıtaş and Süral (2010) with established validity and reliability, and the Approaches to Learning Inventory, adapted into Turkish by

[4] Social Sciences High School
[5] Anatolian Religious High School
[6] Science High School
[7] Anatolian High School
[8] Vocational High School

Çolak and Fer (2007) with established validity and reliability, were used as data collection tools. Permissions for the use of the scales were obtained from the researchers who carried out the adaptation studies. In addition, a set of demographic questions prepared by the researcher to collect students' demographic information was appended to these measurement tools.

The Grasha–Reichmann Student Learning Styles Scale offers the opportunity to conduct a comprehensive analysis by addressing learning styles under six different categories. In this scale, students are categorized into six learning styles—independent, avoidant, collaborative, dependent, competitive and participant—in order to determine their social learning preferences. The scale consists of six sub-dimensions, each comprising 10 items, for a total of 60 items, and is a five-point Likert-type instrument (Sarıtaş & Süral, 2010). Sarıtaş and Süral (2010) carried out the adaptation of the Grasha–Reichmann Student Learning Styles Scale at the higher education level and calculated the Cronbach's alpha reliability coefficient as .802, demonstrating that it is a reliable measurement tool. Dağ and Karamustafaoğlu (2023) administered the scale to a science high school sample and reported an overall reliability coefficient of .809. In the present study, the Cronbach's alpha reliability coefficient was found to be .841. According to Büyüköztürk et al. (2020), if the reliability coefficient is in the range $0.60 < \alpha < 0.80$, the scale can be considered reliable. With the obtained reliability coefficient of 0.841, it was shown that the scale is also a valid and reliable measurement tool at the high school level. For each sub-dimension of the scale, the mean scores obtained were used to classify levels as "low", "medium" and "high" (Sarıtaş & Süral, 2010). Mean scores for the six learning styles were calculated across these three levels. These levels are presented in Table 3.

Table 3: Rating Scheme for the Grasha–Reichmann Student Learning Styles Scale

	Degree of Learning Styles		
Learning Styles	**Low**	**Medium**	**High**
Independent	1.0 – 2.7	2.8 – 3.8	3.9 – 5.0
Avoidant	1.0 – 1.8	1.9 – 3.1	3.2 – 5.0
Collaborative	1.0 – 2.7	2.8 – 3.4	3.5 – 5.0
Dependent	1.0 – 2.9	3.0 – 4.0	4.1 – 5.0
Competitive	1.0 – 1.7	1.8 – 2.8	2.9 – 5.0
Participant	1.0 – 3.0	3.1 – 4.1	4.2 – 5.0

The Approaches to Learning Inventory adapted by Çolak and Fer (2007) was originally developed by Biggs, Kember and Leung in 2004. Students' scores are calculated as the sum of the item scores. The response format is a five-point Likert scale scored as "never true of me (1)", "rarely

true of me (2)", "sometimes true of me (3)", "often true of me (4)" and "always true of me (5)".

The inventory consists of a total of 22 items. Eleven of these items are related to deep learning; 7 of them measure the deep motivation dimension and 4 of them measure the deep strategy dimension. The total score range for the deep approach is between 11 and 55. Example items for the deep approach to learning include "I try to relate what I learn about a topic to what I have learned in other topics" and "I consider myself to have learned sufficiently only when I have studied a topic to the point where I can form my own interpretations".

The other 11 items in the inventory are related to surface learning; 4 of these measure surface motivation and 7 measure the surface strategy dimension. The score range for the surface approach is likewise between 11 and 55. Example items for the surface approach to learning include "The best way to pass exams is to memorize the answers to the questions that are likely to be asked" and "I do not see any need to learn topics that are unlikely to appear in the exam".

In the inventory, the surface approach score is calculated as the sum of the scores obtained from the surface strategy and surface motivation dimensions, while the deep approach score is calculated as the sum of the deep strategy and deep motivation scores. Both the sub-dimension scores and the total scores for the deep and surface approaches can be evaluated separately.

According to the results of the internal consistency analysis, Cronbach's alpha coefficients were found to be 0.79 for the deep approach to learning and 0.72 for the surface approach to learning. These values indicate that the inventory is a reliable measurement tool for both dimensions of approaches to learning (Çolak & Fer, 2007). In the present study, the overall Cronbach's alpha reliability coefficient was calculated as .650. According to Büyüköztürk et al. (2020), if the reliability coefficient is in the range $0.60 < \alpha < 0.80$, the scale can be considered reliable.

Data Analysis

Among the data obtained from 427 students who participated in the study, 39 forms were found to be invalid; thus, the analyses were conducted using 388 valid questionnaires. First, skewness and kurtosis values were examined to determine whether the data were normally distributed, and it was found that all skewness and kurtosis values fell within the range of -1.5 to +1.5. According to Tabachnick and Fidell (2013), skewness and kurtosis values within the range of -1.5 to +1.5 indicate that the data are normally distributed.

Descriptive statistical methods were used to identify high school students' approaches to learning and learning styles. To examine the

relationship between students' approaches to learning and their learning styles, the Pearson correlation test was employed. Pearson correlation is a parametric test used to measure the linear relationship between two continuous variables. It is preferred when the variables are normally distributed and when there are no outliers that might distort the relationship (Cohen, 2020).

To investigate whether students' approaches to learning differed according to school type, a MANOVA test was used. MANOVA (Multivariate Analysis of Variance) is a statistical method used to analyse how multiple dependent variables are simultaneously affected by one or more independent variables. In this study, surface and deep approaches to learning were treated as dependent variables, while school type was treated as the independent variable. When there are linear relationships among the dependent variables, MANOVA provides more powerful and effective results compared to conducting separate ANOVA analyses. This method evaluates the effect of independent variables on the dependent variables while also taking into account the interrelationships among the dependent variables (Tabachnick & Fidell, 2013). For the MANOVA test, the assumption of homogeneity of variances was found to be satisfied ($p = .07$, $p = .68$; $p > .05$).

To examine whether students' learning styles differed according to school type, the chi-square test was employed. The chi-square test is a statistical method used to evaluate the relationship or difference between categorical variables. Since each learning style was categorized as "low", "medium" or "high", the chi-square test was deemed appropriate. This test compares the observed (actual) frequency distribution with the expected frequency distribution. It is widely used particularly in the analysis of categorical data (Field, 2022).

FINDINGS

Findings on Approaches to Learning

The findings regarding high school students' approaches to learning according to school type, together with mean and standard deviation values, are presented in Table 4.

Table 4: Findings on High School Students' Approaches to Learning

		Deep Learning		Surface Learning	
	N	$\underline{X}$	**S.D.**	$\underline{X}$	**S.D.**
School Type					
SBL	83	28.96	5.76	35.51	6.87
AİHL	84	29.46	4.63	35.12	6.31
FL	97	28.35	4.75	35.13	5.52
AL	91	29.55	5.40	35.67	5.71
ML	33	27.36	5.69	34.94	6.88
Total	388	28.95	5.19	35.23	6.09

When Table 4 is examined, it is observed that in this assessment conducted with a total of 388 students, students preferred the surface approach to learning more frequently than the deep approach (M = 35.23 > M = 28.95). The lower standard deviation value in deep learning strategies (SD = 5.19) indicates that the learning behaviours of students who adopt this strategy are more homogeneous. Among those who prefer the deep approach to learning, students attending Anatolian high schools (AL) have the highest mean score (M = 29.55), followed by students in Religious high schools (AİHL; M = 29.46), social sciences high schools (SBL; M = 28.96), science high schools (FL; M = 28.35) and vocational high schools (ML; M = 27.36). In terms of the surface approach to learning, Anatolian high school students (AL) also have the highest mean score (M = 35.42). They are followed respectively by students in social sciences high schools (SBL; M = 35.51), science high schools (FL; M = 35.13), Religious high schools (AİHL; M = 35.12) and vocational high schools (ML; M = 34.94).

Findings on Learning Styles

The findings regarding high school students' learning styles according to school type are presented in Table 5.

Table 5: Findings on High School Students' Learning Styles

Okul Türü		SBL		AİHL		FL		AL		ML			
Öğrenme Stili		**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	***V***	**p**
Independent	Düşük	7	%8.3	8	%9.5	11	%11.3	4	%23.1	9	%27.3	.16	012
	Orta	56	%67.9	60	%71.4	69	%71.2	66	**%72.5**	23	%69.7		
	Yüksek	20	%23.8	16	%19	17	%17.5	21	%4.4	1	%3		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Avoidant	Düşük	41	%56	38	%45.2	59	%60.8	40	%44	15	%45.5	.12	220
	Orta	32	%38	42	%50	35	%36.1	47	%51.6	18	%54.5		
	Yüksek	5	%6	4	%4.8	3	%3.1	4	%4.4	0	%0		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Colloborative	Düşük	19	%22.6	16	%19	21	%12.4	22	%24.2	12	%36.4	.15	036
	Orta	56	%67.9	55	%65.5	64	%66	59	%64.8	18	%54.5		
	Yüksek	8	%9.5	13	%15.5	12	%21.6	10	%11	3	%9.1		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Dependent	Düşük	11	%13.1	11	%13.1	13	%13.4	6	%6.6	6	%18.2	.09	710
	Orta	56	%67.9	64	%76.2	78	%80.4	64	%70.3	23	%69.7		
	Yüksek	16	%19	9	%10.7	6	%6.2	21	%23.1	4	%12.1		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Competitive	Düşük	36	%42.9	31	%36.9	49	%50.5	27	%29.7	17	%51.5	.13	.10
	Orta	38	%46.4	48	%57.1	43	%44.3	54	%59.3	14	%42.4		
	Yüksek	9	%10.7	5	%6	5	%5.2	10	%11	2	%6.1		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Participant	Düşük	23	%27.4	20	%23.8	30	%30.9	20	%22	15	%45.5	.13	082
	Orta	51	%61.9	57	%67.9	63	%64.9	68	%74.7	17	%51.5		
	Yüksek	9	%10.7	7	%8.3	4	%4.2	3	%3.3	1	%3		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		

A significant relationship was found between the independent learning style and school type (V = .16, p = .01). Among vocational high school (ML) students, a low level of independent learning style is more prevalent (27.3%), whereas 72.5% of Anatolian high school (AL) students have a moderate level of independent learning style. A weak but significant relationship was also identified between the collaborative learning style and school type (V = .15, p = .04). While a high level of collaborative learning style is less common among science high school (FL) students (21.6%), 74.7% of AL students display a moderate level of collaborative learning. For the avoidant learning style, the relationship is weak and not significant (V = .18, p = .22); however, the low-level avoidant style ratio of 60.8% among FL students is noteworthy. No statistically significant relationship was found between school type and the other learning styles (dependent, competitive, participant) (dependent: V = .08, p = .71; competitive: V = .13, p = .10; participant: V = .13, p = .08). Overall, the most common category of learning styles across all school types is the moderate level. While ML students have higher rates of low-level learning styles and lower rates of high-level styles, FL and AL students display a more balanced distribution at the moderate level, indicating a more homogeneous structure. These findings reveal that there are meaningful differences between school types in terms of learning styles.

Relationship Between High School Students' Approaches to Learning and Learning Styles

To examine the relationship between high school students' approaches to learning and their learning styles, a Pearson correlation test was conducted and the results are presented in Table 6.

Table 6: Correlation Test Results on High School Students' Approaches to Learning and Learning Styles

Variables		N	r	p
Deep Learning Approach	Independent	388	.46	.00
	Avoidant	388	-.15	.03
	Collaborative	388	.43	.00
	Dependent	388	.41	.00
	Competitive	388	.41	.00
	Participant	388	.46	.00
Surface Learning Approach	Independent	388	.14	.067
	Avoidant	388	.29	.00
	Collaborative	388	.08	.00
	Dependent	388	.19	.00
	Competitive	388	.20	.00
	Participant	388	-.05	.007

When Table 7 is examined, it is seen that there are significant relationships between high school students' approaches to learning and their learning styles. The deep approach to learning shows moderate, positive relationships with the independent ($r = 0.46$, $p < .001$), collaborative ($r = 0.43$, $p < .001$), participant ($r = 0.46$, $p < .001$) and competitive ($r = 0.41$, $p < .001$) learning styles. On the other hand, a weak but significant negative relationship was found between the deep approach and the avoidant learning style ($r = -0.15$, $p < .05$). The surface approach to learning displayed a low-level positive relationship only with the avoidant learning style ($r = 0.29$, $p < .01$). No significant relationships were found between the surface approach and the other learning styles. According to Cohen (2020), correlation levels are classified as low between 0.10 and 0.30, moderate between 0.30 and 0.50, and large between 0.50 and 1.00.

Findings on the Differences in High School Students' Approaches to Learning by School Type

To examine whether high school students' approaches to learning differed according to school type, a MANOVA test was conducted and the results are presented in Table 7. Since deep and surface approaches to learning were treated as separate dependent variables, MANOVA was preferred.

Table 7: Differences in High School Students' Deep and Surface Approaches to Learning by School Type

		Sum of Squares	df	Mean of Squares	F	p	η^2
School Type	Deep Approach	174.31	4	43.58	1.63	.17	.02
	Surface Approach	80.85	4	20.21	.54	.71	.01

When Table 7 is examined, the effect of school type on students' approaches to learning is revealed. It was found that there was no significant difference according to school type in terms of either the deep approach to learning ($F = 1.63$, $p > .05$) or the surface approach to learning ($F = .54$, $p > .05$).

Findings on the Differences in High School Students' Learning Styles by School Type

To examine whether high school students' learning styles differed according to school type, a chi-square test was conducted and the results are presented in Table 8. The preference for the chi-square test was based on the fact that learning styles were categorized as "low", "medium" and "high".

Table 8: Chi-Square Test Results for Differences in High School Students' Learning Styles by School Type

Groups		School Type						X^2	df	p
		SBL	AİHL	FL	AL	ML	Toplam			
Independent	Low	7	8	11	4	9	39	19.55	8	.012
	Med	56	60	69	66	23	274			
	High	20	16	17	21	1	75			
	Total	83	84	97	91	33	388			
Avoidant	Low	46	38	59	40	15	198	10.74	8	.22
	Med	32	42	35	47	18	174			
	High	5	4	3	4	0	16			
	Total	83	84	97	91	33	388			
Dependent	Low	11	11	13	6	6	47	16.45	8	.036
	Med	56	64	78	64	23	285			
	High	16	9	6	21	4	56			
	Total	83	84	97	91	33	388			
Collaborative	Low	19	16	21	22	12	90	5.44	8	.71
	Med	56	55	64	59	18	252			
	High	8	13	12	10	3	46			
	Total	83	84	97	91	33	388			
Competitive	Low	36	31	49	27	17	160	13.38	8	.10
	Med	38	48	43	54	14	197			
	High	9	5	5	10	2	31			
	Total	83	84	97	91	33	388			

Participant	Low	23	20	30	20	15	108	14.00	8	.082
	Med	51	57	63	68	17	256			
	High	9	7	4	3	1	24			
Total		83	84	97	91	33	388			

When Table 8 is examined, it is seen that there is a significant difference in the independent learning style according to school type (X^2 = 19.55, p = 0.012). This finding indicates that the levels of the independent learning style (low, medium, high) differ across school types. It is noteworthy that the independent learning style is more frequently observed at a high level among social sciences high school and science high school students, whereas this level is lower among vocational high school students.

For the dependent learning style, a significant difference was also found according to school type (X^2 = 16.45, p = 0.036). This result shows that the levels of the dependent learning style (low, medium, high) vary across different school types. While Anatolian high school students tend to display a high level of dependent learning style, vocational high school students appear at lower levels.

No significant difference by school type was found for the avoidant learning style (X^2 = 10.74, p = 0.22), the collaborative learning style (X^2 = 5.44, p = 0.71), the competitive learning style (X^2 = 13.38, p = 0.10) or the participant learning style (X^2 = 14.00, p = 0.082).

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

In this study, high school students' learning styles, approaches to learning and their differences according to school type were examined. According to the findings, no significant difference was found in approaches to learning by school type. Students predominantly adopted a surface approach to learning across all school types (M = 5.23). This indicates that high school students tend to prefer more rote-based and surface-oriented strategies in their learning processes. The higher standard deviation for surface learning strategies (SD = 6.09) shows that individual differences are more pronounced among students who use this strategy.

These findings are in line with the study by Yazıcı and Kartal (2020), who examined the approaches to learning of students attending different types of high schools. In their research, it was concluded that approaches to learning did not differ significantly by school type and that students more frequently preferred surface learning strategies. Similarly, the present results are consistent with those of Dikbayır's (2016) study on high school students' learning strategies. Dikbayır reported that school type had no significant effect on learning strategies and that individual differences were spread across a

wider spectrum. In particular, differences between individuals in surface learning strategies were highlighted as being associated with factors such as students' motivation and their perceptions of the learning process. Moreover, the wider distribution of surface learning in certain school types such as vocational high schools (ML) suggests that students in these groups exhibit a more heterogeneous structure in their learning processes. In contrast, the narrower range of individual differences among Anatolian high school (AL) students may point to a more homogeneous structure in their learning processes.

However, in the studies by Çağdaş and Ekinci (2024), which examined deep and surface approaches to learning in the context of mathematics, it was found that students adopted the deep approach more than the surface approach. This discrepancy may stem from factors such as differences in the research sample, the scales used or the subject area examined. In a similar study, Nar (2024) identified significant differences in favour of the deep approach in middle school students' approaches to learning in social studies, both overall and by grade level. In addition, another study by Kartal and Yazıcı (2020) showed that approaches to learning may differ by grade level, suggesting that, although not necessarily dependent on school type, approaches to learning can be influenced by socioeconomic environment, gender and curricula. The findings of Biggs and Tang (2011), which associate the prevalence of surface learning with lack of motivation and inappropriate learning environments, are also compatible with the present study. This indicates that more effective pedagogical strategies are needed to support high school students' learning processes.

In this context, the fact that the learning process is shaped by individual approaches to learning and learning styles points to the need for curricula to be diversified in a way that is responsive to each learner's needs. Individualised approaches to learning processes in different types of schools can not only help students develop strategies appropriate to their learning styles but also encourage them to adopt deeper approaches to learning. In conclusion, while the finding that approaches to learning differ by school type is supported by some studies, it is not supported by others. These contradictory results suggest that approaches to learning are shaped by a range of factors such as individual characteristics, curricula and environmental conditions, and that more comprehensive research is needed in this area.

Despite the school-type variable, the similarity in surface learning tendencies indicates that the current education system directs students towards rote-based and surface strategies. This underlines the need to restructure curricula in a way that supports students' adoption of deep approaches to learning. It is known that the curricula implemented at the 11th grade level are those introduced in 2018 (MEB, 2018). The fact that students in all school

types that admit students with different achievement levels through the LGS examination adopt a surface approach suggests that students tend to prefer exam-oriented, rote and short-term learning (Aktunç, 2023; Teoh & Yap, 2015). Yet it is well established that students who adopt a deep approach achieve more detailed, understanding-based and long-term learning (Alkhateeb & Bani-Milhem, 2020; Arslan, 2017). Eğmir and Çelik (2021), in their study on the education system, also drew attention to its rote-oriented nature.

The finding that high school students' learning styles differ by school type suggests that learning styles may be related to the type of school attended. For example, the independent learning style is more frequently observed in certain school types, while it is less preferred in others. The avoidant learning style is not observed at all in some types of schools, whereas it appears at lower levels in others. In the collaborative learning style, some school types show a balanced distribution, while in others there is a concentration at low levels.

These findings support the significant relationship between high school type and learning styles reported in the study by Çakır and Akbaş (2013). In that study, it was noted that students predominantly adopted the independent learning style and that school type had an effect on this preference. However, the studies by Yıldız (2017) and Zencir (2024) reported that learning styles did not generally differ significantly by school type, but were more strongly associated with individual characteristics and environmental factors.

Similarly, Azarkhordad and Mehdinezhad (2016) found that dependent and participant learning styles were generally dominant, but that independent and avoidant styles came to the fore depending on gender. Dağ and Karamustafaoğlu (2023) reported that science high school students predominantly adopted competitive and collaborative learning styles. The variety of findings in the literature indicates that learning styles can be influenced by variables such as school type, environment, research context and gender, and that these variables play an important role in learning processes.

Significant relationships were also identified between high school students' approaches to learning and learning styles. The deep approach to learning showed moderate, positive relationships with independent, collaborative, participant and competitive learning styles, and a weak but significant negative relationship with the avoidant learning style. The surface approach, on the other hand, displayed a low-level positive relationship only with the avoidant learning style and no significant relationship with the other styles. These findings support the meaningful relationship between learning styles and learning strategies reported by Güven (2004). In that study, it was

emphasised that students with certain learning styles more frequently used strategies consistent with those styles. This underscores the importance of individual tendencies in students' learning processes. However, in Yıldız's (2017) study, no significant relationship was found between learning styles and approaches to learning. These discrepancies suggest that learning processes may be influenced by both individual and environmental factors.

The correlation analyses revealed positive relationships between the deep approach to learning (associated with higher-order learning skills) and the independent (self-directed), collaborative (interaction-oriented) and participant (keen to share/teach knowledge and ideas) learning styles. These findings indicate that students who adopt a deep approach to learning tend to have a more interaction-oriented and analytical way of thinking (Çolak & Fer, 2007; Sarıtaş & Süral, 2010). In addition, Çolak (2015) found a relationship between students who prefer deep approaches to learning and those who adopt collaborative and competitive learning styles. The fact that the avoidant learning style (characterised by withdrawal from learning and interaction) shows a weak negative relationship with the deep approach suggests that this style may be associated with more passive and surface learning strategies (Aktunç, 2023; Dağ & Karamustafaoğlu, 2023). These findings highlight the need to redesign school curricula and learning environments to support students' adoption of deep approaches to learning. Furthermore, future research with different age groups and educational levels is recommended to gain a better understanding of the relationships between learning styles and approaches to learning.

The MANOVA and chi-square analyses revealed that the effect of school type on approaches to learning and learning styles is limited. However, the significant differences found in independent and dependent learning styles suggest that these style categories are more sensitive to school climate. This finding is consistent with studies that argue that learning styles can be influenced by individual differences and environmental factors. For example, Eğmir and Çelik (2021) emphasised that students' approaches to learning are sensitive to individual and environmental factors. Similarly, another study showed that learning styles can differ significantly by high school type and that female students tend to be more dependent and collaborative learners than male students (Yılmaz & Keleşoğlu, 2014). In Öztekin's (2012) study, learning styles of students from different types of high schools were examined and found to differ according to school type; it was also determined that female students were more likely to have dependent and collaborative styles than male students.

In the systematic review conducted by Cevher (2017), academic studies on learning styles were examined and the relationships between learning styles and various variables were discussed. This review concluded

that learning styles are influenced by individual differences, but did not find clear evidence regarding the effect of school type. Nevertheless, some studies report findings that contradict these results. For instance, in a study by Demir et al. (2019), significant differences were found in approaches to learning across different school types. This suggests that the effect of school type on approaches to learning is not entirely limited and that a more complex relationship may be at play. Moreover, a systematic review on learning styles indicated that they are influenced not only by individual characteristics but also by environmental factors (Kaya, 2020). In conclusion, although the significant differences found in the independent and dependent learning style categories suggest that these styles may be more sensitive to school climate, the boundaries of school-type effects and the other factors involved in this relationship need to be examined more comprehensively.

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Pre-Service Primary Teachers' Competencies in Designing STEM-Integrated Science Lessons Based on Curriculum Learning Outcomes

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ABSTRACT

This study examines the competencies of pre-service primary teachers in designing STEM-integrated lesson plans based on selected learning outcomes from the science curriculum. Six pre-service teachers were each assigned one curriculum outcome and asked to create a STEM-based lesson plan aligned with science, technology, engineering, and mathematics components. The lesson plans were evaluated using a five-dimension rubric and a three-dimension STEM rubric. Content validity was ensured through expert review, and interrater reliability was established using Cohen's Kappa. Descriptive statistics were used to determine the general quality of the lesson plans, while the Friedman test examined differences among the STEM integration, engineering design, and assessment dimensions. Findings showed that participants performed well in aligning outcomes with content and designing student-centered instructional processes. However, engineering design, technology integration, and assessment practices were the weakest areas. Engineering design received the lowest scores, and significant differences were found among the three dimensions. The results indicate that pre-service teachers need stronger preparation in engineering design and STEM-based assessment practices. The study highlights the necessity of more practice-oriented STEM training within teacher education programs.

Keywords: STEM education, pre-service teachers, lesson planning, engineering design, assessment.

INTRODUCTION

In the 21st century, where science, technology, and societal needs are rapidly changing, the need for a holistic educational approach that enables individuals to solve complex problems, be productive, and develop innovative thinking skills is steadily increasing. In this context, STEM education (Science, Technology, Engineering, Mathematics) stands out as an important educational concept that has gained global recognition with its interdisciplinary structure. STEM is not merely an acronym formed by bringing together the names of science, technology, engineering, and mathematics; it is a comprehensive educational approach that aims to teach these four disciplines in an integrated manner, ensure students' active participation in real-life problem-solving processes, and enable them to use scientific knowledge, engineering design, technological tools, and mathematical reasoning together throughout these processes (Bybee, 2013; Kelley & Knowles, 2016).

Studies in the literature show that STEM education facilitates students' understanding of conceptual knowledge and supports the development of 21st-century skills such as problem solving, critical thinking, creativity, collaboration, communication, and metacognitive awareness (Breiner et al., 2012; English, 2016; Honey et al., 2014). By transforming students from passive recipients of knowledge into active problem solvers, designers, and producers, STEM is considered a strategically important approach in educational, economic, and societal terms (National Research Council [NRC], 2011; National Science Board, 2014). Pedagogically, STEM education advocates for the integration of disciplines within real-life contexts rather than teaching them separately. Within an engineering design cycle, students use scientific concepts, produce with technological tools, conduct mathematical analyses, and test and refine their designed solutions (Kelley & Knowles, 2016). This cycle shows that learning is not merely acquiring information but a holistic process that includes doing, producing, testing, improving, and reflecting. The importance of STEM education is not limited to pedagogical reasons alone. Rapidly growing fields such as Industry 4.0, digitalization, artificial intelligence, robotics, biotechnology, and renewable energy are directly based on STEM knowledge and skills. Therefore, STEM education is regarded as a strategic field for training a qualified workforce and increasing national innovation capacity (National Science Board, 2014; Toulmin & Groome, 2007). Furthermore, the level of scientific literacy in societies is critically important for individuals' ability to make informed decisions in daily life. STEM education is a crucial tool for individuals to develop scientific thinking habits and adapt to technological change (Bybee, 2013). In this context, the effective reflection of STEM in learning environments directly depends on teachers' competencies in planning and implementing this approach.

International literature indicates that pre-service teachers' STEM lesson planning processes enhance their integration skills, increase their interdisciplinary thinking capacities, and strengthen their self-efficacy (Hsu, Purzer & Cardella, 2011; Guzey, Harwell & Moore, 2014). In Türkiye, integrating STEM education into teacher education—particularly at the primary level—has been increasingly regarded as a necessity in recent years. Pre-service teachers' competencies regarding STEM pedagogy directly influence the quality of classroom practices; therefore, the need for STEM-focused applications at the undergraduate level continues to grow (Çorlu, Capraro & Capraro, 2014). Additionally, studies conducted with pre-service primary teachers in the Turkish context that deeply analyze the lesson-plan development process remain limited (Saraç & Doğru, 2021; Tezel & Yaman, 2017). For this reason, enabling pre-service teachers to develop STEM-based lesson plans grounded in different science learning outcomes and evaluating this process systematically will make significant contributions to the field. For this purpose, the learning outcomes in the science curriculum were

examined, and it was determined that the outcomes "identifying soil types," "describing the direction and speed of motion," "recognizing factors affecting plant growth," "explaining balanced nutrition," "explaining the structure of the Earth's crust," and "identifying energy sources" were suitable for STEM design. These outcomes are associated with real-life contexts and allow students to engage in modeling, experimentation, data collection, engineering design, and problem-solving processes. In this context, the development of STEM lesson plans by pre-service primary teachers based on these outcomes provides a critical experience for demonstrating their ability to integrate both pedagogical content knowledge and engineering design processes.

In line with this purpose, the following research questions were addressed in the study:

1. How do the STEM lesson plan development scores of pre-service teachers distribute across the sub-dimensions of the rubric?
2. Is there a significant difference among the scores obtained in the STEM integration, engineering design process, and assessment dimensions?

METHOD

Research Design

This study was structured within a descriptive survey design based on quantitative research methodology, as it aimed to quantitatively examine the rubric scores of pre-service primary teachers' STEM-based lesson plans developed according to science learning outcomes. In descriptive survey designs, an existing situation is presented as it is, without any intervention, and the level of the situation is quantitatively described through the obtained data.

In this study, the rubric scores of the STEM lesson plans prepared by the pre-service teachers were considered as indicators of the existing situation; the overall level of the scores and the distribution of the scores across the rubric dimensions were examined. No experimental procedure, group comparison, or analysis of relationships between variables was conducted; instead, the goal was solely to "numerically reveal the current level of competence." In this respect, the study can be evaluated within the single-survey model.

Data Collection Tool

In this research, the "STEM Lesson Plan Evaluation Rubric," developed by the researcher to assess the STEM-based lesson plans created by pre-service teachers, was used as the data collection tool. The rubric was

created by considering the relevant literature and learning outcomes in the science curriculum, and content validity was ensured through expert review. The developed rubric and its scoring are presented in Table 1.

Table 1. STEM Lesson Plan Evaluation Rubric

Dimension	1 (Very Inadequate)	2 (Partially Adequate)	3 (Adequate)	4 (Highly Adequate)
1. Learning Outcome–Content Alignment	The outcome is misinterpreted; most of the content is inconsistent with the outcome.	The outcome is partially interpreted correctly; inconsistencies exist in the content.	The outcome is interpreted correctly; the content is largely consistent.	The outcome is fully interpreted; the content is fully aligned.
2. STEM Discipline Integration	STEM disciplines are not integrated.	Integration is limited; 1–2 disciplines are used superficially.	Integration is largely achieved; 3 disciplines are aligned.	All STEM disciplines are naturally and holistically integrated.
3.Engineering Design Process	No design process; only an activity is provided.	Some stages of the process are missing or superficial.	Most stages of the process are implemented.	The engineering design cycle is fully and accurately implemented.
4. Teaching–Learning Process	The process is lecture-based and not student-centered.	Student-centered elements are limited and inconsistent.	Student-centered activities are largely included.	The process is fully student-centered, interactive, and constructivist.
5. Assessment	Assessment tools are insufficient or misaligned with the outcome.	Assessment tools are limited; only one type of question is used.	Multiple appropriate assessment tools are used.	High-level, varied, and STEM-appropriate assessment tools are used.

Thus, each lesson plan can receive a minimum of 5 and a maximum of 20 points. In line with the research question, both total rubric scores and scores for each subdimension were analyzed using descriptive statistics (mean, standard deviation, minimum–maximum).

Content validity of the rubric was ensured by three experts in science education, teacher education, and STEM education. Experts evaluated each item as "appropriate," "partially appropriate," or "not appropriate," and the Content Validity Index (CVI) was calculated using Davis' (1992) technique. CVI values for all items ranged between 0.80 and 1.00, indicating sufficient content validity.

In addition, to determine the reliability of the rubric, two independent raters scored the lesson plans according to the rubric; inter-rater agreement was calculated using Cohen's Kappa coefficient and found to be .87. This value is considered "high agreement" in the literature. Therefore, it can be stated that the rubric used in this study reliably produced quantitative scores regarding pre-service teachers' STEM lesson plans.

For the second research question, the "STEM Lesson Plan Evaluation Rubric" was also used to score the STEM-based lesson plans developed by the pre-service teachers. Scores obtained from the STEM integration, engineering design process, and assessment subdimensions constituted the primary quantitative data compared in the research question. These three dimensions and their criteria are presented below:

Table 2: Three-Dimension STEM Rubric

Dimension	Definition	1(Very In.)	2(Partially Ad.)	3 (Adequate)	4(Highly Ad.)
1.STEM Discipline Integration	The degree to which science, engineering, mathematics, and technology are integrated	No integration	1–2 disciplines used in a limited way	3 disciplines aligned	4 disciplines fully integrated
2. Engineering Design Process	Implementation of problem definition, design, testing, improvement, and sharing stages	No process	Stages missing/superficial	Most stages implemented	All stages fully implemented
3. Assessment	Appropriateness, variety, and STEM alignment of the assessment tools used	Not appropriate	Limited and single-type	Appropriate and varied	High-level, diverse, and performance-oriented

Content validity of this three-dimensional STEM Lesson Plan Rubric was ensured through expert opinions obtained from three academics in the field. Using Davis' (1992) method, the Content Validity Index values were

found to range between .80 and 1.00. Reliability was examined through ratings by two independent evaluators, and Cohen's Kappa values ranged from .84 to .88, with an average of .86, indicating high inter-rater agreement. These findings demonstrate that the rubric is a valid and reliable measurement tool for quantitatively assessing pre-service teachers' STEM lesson plans.

Data Collection Process

In this study, the aim was for pre-service teachers to develop STEM-based lesson plans grounded in different science learning outcomes and for this process to be systematically evaluated. For this purpose, the learning outcomes in the science curriculum were examined, and it was determined that the outcomes "identifying soil types," "describing the direction and speed of motion," "recognizing factors affecting plant growth," "explaining balanced nutrition," "explaining the structure of the Earth's crust," and "identifying energy sources" were suitable for STEM design. Each of these outcomes was deemed appropriate for the study because they allow incorporation of STEM components such as engineering design, problem solving, modeling, data collection, and technology integration.

Six pre-service teachers were randomly assigned one of these outcomes, and they were asked to develop a STEM-based lesson plan aligned with the assigned outcome. To ensure a basic level of standardization in lesson plan preparation, participants were provided with a brief guideline on the components of the STEM approach, the engineering design cycle, and student-centered activity design; however, content, method, and material choices were left entirely to the participants to preserve originality.

The lesson plans developed by the pre-service teachers constituted the quantitative dataset of the research. The data collection tools were the STEM Lesson Plan Evaluation Rubrics directly related to the two research questions. The comprehensive five-dimension rubric was used to answer the first research question, while the three-dimension rubric (STEM integration, engineering design, assessment) was used for the second question. Both rubrics were structured with a 1–4 scoring scale, thus generating fully quantitative data.

The lesson plans were scored independently by two raters, and the scores were transferred into the dataset. Since the data collection process relied solely on the teacher candidates' lesson plans, no implementation, observation, or interview was conducted; the study is therefore characterized as a purely quantitative descriptive document analysis.

Data Analysis

Data analysis in this research was based on the quantitative scores obtained from the STEM lesson plans of six pre-service teachers. For the

first research question, total rubric scores and subdimension scores were analyzed using descriptive statistics including mean, standard deviation, minimum–maximum, and median values.

Due to the small sample size (n = 6), normality was examined using the Shapiro–Wilk test. Since normal distribution assumptions were not met, the second research question—comparing STEM integration, engineering design process, and assessment scores—was analyzed using the Friedman Test. When significant differences were found, pairwise comparisons were conducted through the Wilcoxon Signed-Rank Test with Bonferroni correction. The significance level in all analyses was set at $p < .05$.

FINDIGS

In this section, the findings obtained in line with the two research questions are presented by analyzing the rubric scores of the STEM-based lesson plans developed by the pre-service teachers based on different science learning outcomes. The findings are based on both the five-dimension general rubric scores and the comparative scores obtained from the three-dimension quantitative rubric.

To answer the first research question, the total scores obtained by six pre-service teachers from the five dimensions (learning outcome–content alignment, STEM integration, engineering design, teaching–learning process, assessment) were determined. These rubric scores ranged between 11 and 18. This distribution indicates that the pre-service teachers generally possess a moderate level of competency in developing STEM lesson plans. Table 4 presents the scores of the pre-service teachers across the dimensions.

Table 4. Pre-service Teachers' STEM Lesson Plan Development Scores

Dimension	Min	Max	Mean ($\bar{X}$)	Standard Deviation (SD)
Learning Outcome–Content Alignment	2	4	3.33	0.52
STEM Discipline Integration	1	4	2.83	1.07
Engineering Design Process	1	3	2.00	0.63
Teaching–Learning Process	2	4	3.16	0.75
Assessment	1	3	2.00	0.89
Total Rubric Score	11	18	15.00	2.00

Examining the dimensions in Table 4 shows that the highest mean score belongs to the learning outcome–content alignment dimension, indicating that the participants correctly interpreted the selected learning

outcomes and successfully aligned them with the lesson content. Teaching–learning process scores were also relatively high, showing that the pre-service teachers were sufficiently competent in designing student-centered activities.

In the STEM discipline integration dimension, although the science and mathematics components were adequately integrated, noticeable deficiencies were observed in technology and engineering integration. Engineering design process scores ranged from low to moderate; only two of the six participants fully implemented the design cycle (problem definition–design–testing–improvement). The lowest scores were observed in the assessment dimension; only one participant used diverse tools that included both process and product evaluation.

To evaluate the data related to the second research question, the normality of the scores was examined with the Shapiro–Wilk test due to the study being conducted with six participants. Normality was not achieved for the three dimensions, and the Friedman Test was used for comparisons. The Friedman test results indicated a statistically significant difference among the three dimensions. The Wilcoxon pairwise comparisons conducted to determine the source of this difference are presented in Table 5.

Table 5. Wilcoxon Multiple Comparisons

Comparison	Z	p (adjusted)	Result
STEM Integration – Engineering Design	-2.20	.028	Not significant
STEM Integration – Assessment	-2.02	.042	Not significant
Engineering Design – Assessment	-0.12	.90	Not significant

The findings in Table 5 indicate that pre-service teachers particularly need improvement in the engineering and assessment components of STEM lesson plan development. Engineering design process scores were markedly lower than the other two dimensions, while there was no significant difference between STEM integration and assessment scores. The lowest performance was observed in engineering design, followed by the assessment dimension.

RESULTS AND DISCUSSION

The purpose of this study was to examine the quality of STEM-based lesson plans developed by pre-service primary teachers based on different science learning outcomes and to reveal their levels of competence in terms of content, disciplinary integration, engineering design, and assessment dimensions. The findings indicate that while the pre-service teachers possess

a basic level of knowledge and awareness regarding the STEM approach, they experience notable difficulties particularly in components that require practical application.

The results demonstrate that the pre-service teachers were able to interpret the learning outcomes accurately and establish meaningful connections between the outcomes and the instructional content. The high mean score in the learning outcome–content alignment dimension suggests that the participants had achieved a sufficient level of curriculum literacy, which is also consistent with previous research (Çorlu, Capraro & Capraro, 2014). Additionally, high scores in the teaching–learning process dimension indicate that the participants were capable of designing student-centered activities, effectively using their pedagogical content knowledge, and structuring learning processes in line with constructivist principles.

In contrast, lower scores in the STEM integration, engineering design process, and assessment dimensions reveal that the pre-service teachers exhibited limited competencies in the practical and implementation-focused aspects of STEM education. In the STEM integration dimension, science and mathematics disciplines were more successfully incorporated, whereas technology and engineering components were often superficial or only partially integrated. This trend may stem from limited technical knowledge regarding digital tool usage or from perceiving technology integration merely as the use of presentation tools. This pattern aligns with international literature, which frequently emphasizes stronger integration of science and mathematics compared to engineering and technology among pre-service teachers (Kelley & Knowles, 2016).

The engineering design process was identified as one of the most challenging areas for the participants, with many lesson plans incorporating only "model construction" activities while neglecting critical stages such as problem definition, testing, and improvement. This finding is consistent with studies indicating that pre-service teachers struggle to implement the engineering design cycle and to articulate its pedagogical and cognitive rationale (Hsu, Purzer & Cardella, 2011). Accordingly, it becomes evident that engineering design should be addressed in teacher education programs more systematically and through hands-on, process-oriented practices.

The assessment dimension yielded the lowest mean score, suggesting that the pre-service teachers lacked sufficient experience with performance-based, process-oriented, and product-focused assessment tools within STEM contexts. As noted by Honey, Pearson, and Schweingruber (2014), insufficient assessment practices in STEM instruction can hinder the visibility of authentic learning outcomes and restrict students' development in STEM applications. The findings of this study similarly show that the participants tended to rely on traditional assessment tools and had not yet developed advanced assessment competencies.

The results of the Friedman test revealed significant differences among the three key STEM dimensions, indicating that the pre-service teachers were unable to integrate STEM components at comparable levels. The lowest scores in the engineering design and assessment dimensions highlight that the participants require further support in performing advanced and practice-oriented aspects of STEM instruction. This suggests that transferring theoretical knowledge into practical teaching processes remains a challenge for many pre-service teachers.

Overall, this study demonstrates that while pre-service primary teachers possess certain strengths in developing STEM-based lesson plans—particularly in interpreting learning outcomes, aligning content, and designing student-centered learning processes—they exhibit substantial areas for improvement in engineering design, technology integration, and assessment. Based on these findings, it is recommended that teacher education programs:

- incorporate more systematic and practice-based instruction on the engineering design process,
- integrate technology-focused STEM components (e.g., coding, digital design, data collection tools) into the curriculum,
- provide theoretical and practical training on performance-based and process-oriented assessment within STEM contexts,
- offer structured mentorship during the lesson plan development process,
- support pre-service teachers through authentic classroom-based STEM activities to strengthen their design and implementation skills.

In conclusion, the study reveals that pre-service primary teachers possess basic competencies in developing STEM-oriented lesson plans; however, they need further support in mastering advanced components of STEM instruction. Restructuring teacher education curricula and practicum experiences in alignment with the nature of the STEM approach is expected to enhance the quality of future classroom practices.

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Work Engagement in Schools

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ABSTRACT

The main purpose of this study is to examine the role of teacher work engagement in the sustainability and transformation of educational institutions as learning-oriented systems. Work engagement is a positive, energetic, and cognitive mental condition where teachers exhibit long-term commitment, professional energy, and intense engagement in their work. Integrating into the framework of the Psychological Conditions Model and the Job Demands-Resources (JD-R) theory, the proposed study is aimed at discussing the interactions between individual resources, including self-efficacy, resilience, intrinsic motivation, and organizational structures, such as supportive leadership, professional development opportunities, and collaborative school cultures, in strengthening the engagement of teachers. An increase in teacher activity leads to a rise in the quality of instruction provided, student achievement and organizational commitment which in turn creates innovation and continuous improvement in the school. The issues that impede the ability to maintain sustained engagement are also discussed in the study, including work overload, work-related emotional labor, and institutional support. The focus is made on the significance of transformational leadership, psychological safety, and fair allocation of resources to develop the environments where educators could flourish. The conceptual model suggested indicates the necessity of the strategic alignment of individual and organizational factors in order to improve engagement, strengthen professional identity, and secure educational excellence. Finally, this Study promotes the idea of systemic solutions, focusing on teacher well-being and involvement to be the inherent factors of sustainable and future-oriented learning communities.

Keywords: Work engagement, Teacher motivation, Transformational leadership, Organizational well-being, School culture.

INTRODUCTION

Over the past decades, education has focused on the best ways to improve the teaching and learning experiences. Teacher work engagement has emerged as a key factor at professional growth (Koch, et al., 2015). Work engagement describes the extent to which a teacher is energetic, dedicated, and absorbed in their work. These facets positively impact the educator's job performance and student outcomes. As a result, the educational research community has positively associated teacher engagement with the enthusiasm, persistence, team work, and collaboration necessary to create a productive learning environment (Gamero-Burón & Lassibille, 2018). Work engagement has its origins in the research area of positive psychology. Kahn (1990) described the psychological conditions of meaningfulness, safety, and availability, which need to exist in employees. Building on this, the Job Demands-Resources (JD-R) model, explains additional factors of motivation and work-placed well-being i.e. job demands and resources (Bakker & Demerouti, 2008). In education, these conditions describe supportive leadership, appropriate teacher workload and resources as factors that positively impact teacher motivation and resilience. While personal job satisfaction is important, it is not the sole focus of work engagement. Fully engaged teachers contribute positively to the school culture, improve the quality of instruction, and raise students' motivation.

However, disengaged teachers may experience burnout, diminished productivity, and ineffective instruction, which have far-reaching effects on personal and organizational results. Various elements determine the level of teachers' engagement. For instance, intrinsic motivation is crucial. When teachers find meaning in their work, they show high levels of engagement and zeal. Supportive and authentic leadership further, positively influences school climate, which in turn fosters collaboration and psychological safety (Shao et al., 2025). In the contrary, having too much to work on, added to the lack of resources and emotional drain, will reduce engagement and raise the chances of burnout. This was evident during the COVID-19 pandemic, especially among teachers, as they dealt with emotional and professional challenges of a magnitude they had not experienced before. Bakker et al. (2008), define job engagement as a "positive, fulfilling, effectively motivating state of work-related subjective well-being." Work engagement is a significant indicator of the quality of working life.

Moreover, it is a significant element in comprehending behaviors such as labor transfer, job reluctance, and absenteeism (Hakanen et al., 2006). So, we can say that how engaged employee are at work is a very crucial aspect in how well they do their jobs and how productive they are. Furthermore, it represents a commitment one individual demonstrates towards another person, an idea, an organization, or a concept seen as superior to oneself, with a responsibility that must be fulfilled (Zahed-Babelan et al., 2019). Work engagement is the

cognitive belief condition of the psychological affiliation of the employee with her/his work (Kanungo, 1982). When employees psychologically identify with their job, they become enthusiastic, effective, and eager to meet the demands of their profession when doing work-related tasks (Maslach & Leiter, 1997; Schaufeli & Bakker, 2004). It is crucial for job engagement to believe in the work and embrace its principles and goals (Gülbahar, 2017). Work engagement is an important part of improving employee performance and, consequently, organizational productivity. For policymakers and school administrators seeking to improve school performance and retain teachers in their profession, understanding what increases teachers' job commitment has become increasingly important. Studies show that programs designed to support teacher well-being and engagement can have meaningful impacts-not just for teachers themselves, but also for their students and the education system as a whole (Tortosa Martínez et al., 2024).

Engagement at work, which is a construct used to describe work vigor, dedication, and absorption, has been found to be a critical construct of occupational well-being in the education sector (Schaufeli & Taris, 2013). Highly engaged teachers, in schools, are associated with high quality of instructions, improved student performance, and reduced turnover rates (Taris & Schaufeli, 2008; Rich et al., 2010). However, the stressful aspect of teaching, which involves heavy workloads, emotional work, and leadership roles, also increases burnout as a negative condition, which undermines engagement and school performance. The antecedents of work engagement have been well theorized in the organizational context (Bakker & Demerouti, 2008) but there is a paucity of empirical studies defining the contextual, personal and organizational predictors of engagement in non-Western settings and non-teacher employee. This gap highlights the necessity of a planned study of the influenced factors that maintain an engagement between school personnel, which may inform interventions that can improve educator well-being and student achievement. Accordingly, the study aims to explore the main factors that shape teachers' engagement at work. It also looks into the challenges and opportunities teachers face as they work to stay motivated and passionate in today's ever-changing education environment.

CONCEPTUAL FRAMEWORK

Work Engagement

Work engagement is an excellent, satisfying, affective-motivational condition of work-related well-being that serves as the antithesis of job burnout. Engaged personnel exhibit elevated energy levels and demonstrate passionate involvement in their job (Bakker et al., 2008). Work engagement is a positive, active work-related state that is defined by absorption, dedication, and vigor (Schaufeli et al., 2004). Personal energy's behavioral investment is accompanied by work engagement, a motivational psychological state that is independent,

persistent, and pervasive (Schaufeli & Bakker, 2006). One of the most recognizable definitions of engagement was introduced by Kahn (1990): "The alignment of the selves of organizational members with their work roles." According to Schaufeli et al. (2002), work engagement is "a positive, fulfilling, work-related state of mind characterized by vigor, dedication, and absorption" and has the potential to impact employee health. It is also a state of complete and ardent work involvement (Rich et al., 2010). Maslach and Leiter (2008) defined engagement as the antithesis of fatigue; engaged employees experience a sense of energetic and effective connection with their work. Consequently, engagement is defined by vitality, involvement, and professional efficacy, which are the direct antithesis of the three fundamental exhaustion dimensions. Engagement will provide a more significant contribution to the nomological network as a distinctive construct that contributes exceptional value (Halbesleben & Wheeler, 2008).

Work engagement reflects a growing positive mental state in and around the educational space. It comprises of three main components: vigor, dedication, and absorption. The vigor component includes the positive energy and mental strength teachers have in order to persist for a prolonged time, especially in challenging times. Dedication is the component that involves the profound value and meaning individuals attach to one's work (Bakker et al., 2008). It inspires educators to do more than the basic expectations and work towards meaningful experiences for the learners. Furthermore, absorption describes the state in which individuals concentrate so intensely on the task at hand that they lose awareness of time. The multi-faceted concept of work engagement explains the optimal state in which educators perform their duties (Basikin, 2007).

Work engagement significantly impacts employees' performance. The enthusiasm and concentration essential to work engagement enable people to realize their full potential in their roles. This vigorous concentration improves the quality of their fundamental job duties. They possess the ability and the will to focus only on the job at hand. The work engagement of teachers is rapidly gaining prominence as a relevant aspect of their professional achievement and general contribution in schools. It can be described as the positive and fulfilling attitude towards work, which is characterized by enthusiasm, devotion, and engagement. This was the idea of Schaufeli et al. (2006) who conceptualized engagement in the context of positive psychology, where engagement increase the well-being and effectiveness of educators.

Vigor explains how teachers can be enthusiastic and mentally strong in their work. Individuals who are very vigorous such as energy-filled work hard and maintain their energy even amidst challenges. Dedication implies a personal desire to be attached to their job, when teachers think that their contribution is important and are proud of their success. This commitment compels them to go out of the ordinary job requirements. Absorption occurs when the educator gets absorbed in the work which makes him to lose the time in which he is completely involved with teaching.

Teachers who are not deeply engaged teachers are more satisfied with their jobs and are more committed to their schools. This is a well relationship with the student outcome that helps to highlight the importance of engagement in learning. Full engagement of teachers does not only help them to grow professionally but also makes their lessons rich to their students.

Teacher engagement is influenced by both personal aspects and school environments. Such characteristics as self-efficacy, or confidence in abilities, have a significant influence. It is mentioned in (Li et al., 2025) that when teachers are motivated, they are better able to offer their instruction. In the meantime, positive school environments and collaboration contribute to the enhancement of self-efficacy and building a more solid relationship.

The engagement involves multiple dimensions, such as cognitive, emotional, and social, each of which affects the relations that teachers have towards their work (Dai & Wnag, 2023). Mental activity is known as cognitive engagement in which one attempts to fulfill job requirements by expending mental energy in tasks like lesson planning or engaging students in more challenging ways. Emotional engagement indicates the level of care teachers have about their job; in the cases of emotional engagement, teachers tend to develop or become more innovative in the classroom.

By motivating faculty through inspiration and encouragement, transformational leaders can boost the teacher engagement in which all feel encouraged and engaged. This kind of leadership is aligned to the results of (Huo & Wang, 2024) that indicated that nurturing style of management is the one that engaged teachers react to well.

Teachers are also safeguarded by work engagement against burnout and quit. So far as teaching is an emotional process, engagement allows educators to remain resilient to stressors caused by heavy workloads or disruptive student behavior (Li et al., 2025). It is their personal values about education that make them grounded because they are intrinsically motivated.

With the evolving needs of education in every part of the world, it is imperative to know the factors that motivate teachers to be engaged so as to be able to make proper institutional policies. The provision of school settings that promote work engagement is not only beneficial to individual educators but also to be able to create loyal, high-achieving learning communities that are centered on quality teaching outcomes.

Summary definition and sources of the concepts of work engagement, vigor, dedication, absorption and engagement vs. burnout are included in Table 1.

Table 1. Overview of Work Engagement Key Concepts and Definitions

Theory / Concept	Brief Definition	Key source
Work Engagement	A positive, fulfilling work-related state characterized by vigor, dedication, and absorption.	Schaufeli & Bakker (2004, 2010)
Vigor	High levels of energy, persistence, and mental resilience while working.	Schaufeli et al. (2002)
Dedication	Strong sense of significance, enthusiasm, inspiration, pride, and involvement in one's work.	Schaufeli et al. (2002)
Absorption	Full concentration and being deeply engrossed in work, where time passes quickly.	Schaufeli et al. (2002)
Engagement vs. Burnout	Engagement = energy, involvement, effectiveness; Burnout = exhaustion, cynicism, inefficacy.	Maslach & Leiter (1997, 2008)

Historical Development of the Work Engagement

Soane et al. (2012) developed a model of engagement comprising three fundamentals: work role focus (a particular defined work role facilitating engagement), activation a response to stimuli that elicits cognitive responses, and positive affect the experience of consciously accessible emotions), based on the studies. Their aim was to create a novel metric for employee engagement grounded on Kahn's framework, conceptualization from 1990. They contended that employee involvement is a three-dimensional concept including intellectual, social, and emotive components. The significance of work engagement for educational institutions is undeniable. It is proven that teachers who are more engaged create and preserve positive and productive learning environments which, in turn, enhances students' learning and overall success (Li et al., 2025). The benefits of engagement are differentiated, primarily, on the personal level of the teacher and subsequently, on the performance level of the students. Engaged teachers demonstrate higher levels of creativity and perform their tasks with more diligence. They pursue professional advancement and exhibit lower levels of burnout. The reciprocal effect of teacher engagement improves motivation and learning in students throughout the school (Sudibjo & Riantini, 2021).

The idea of work engagement stems from different theories. Kahn (1990) first described it as the "the physical, mental, and emotional" effort one puts in "to one's job." This paved the way for Schaufeli et al. (2002) to create models where engagement consists of three components: vigor, dedication, and

absorption. Furthermore, the JD-R model explains how the right job resources triggers motivation and engagement, something teachers who handle heavy workloads need.

Importance of Work Engagement in Schools

The importance of work engagement stretches beyond the individual and impacts the overall success of schools. Engaged teachers, for instance, improve and lead innovative teaching methods, support their schools, and promote positive school cultures-all of which contribute to the formation of thriving learning communities (Li et al., 2025). Hence, the necessity of fostering a culture of engagement in schools, which begins a positive cycle of fully engaged teachers who support the schools and positively impact learning and motivation of their students (Landqvist & Schad, 2022). Despite this, a considerable number of teachers still report feelings of disengagement, being trapped by higher demands and little support. This, and the subsequent lack motivation in schools, highlights the need for tailored engagement support programs for schools of all types (Basikin, 2007). According to Schaufeli and Bakker (2010), understanding the evolution of work engagement assists education leaders like principals and policymakers in figuring out methods to elevate teachers' passion and commitment levels. Positive leadership and opportunities for teachers' professional growth foster a sense of joy, which in turn contributes to improved student success. The engagement of teachers and other staff members at the workplace is slowly turning out to be an important factor that can influence the performance of an individual as well as the overall performance of the institution in the learning and teaching context. Active teachers have higher chances of demonstrating a better quality of instruction, classroom control, and perseverance in the profession (Donovan & Wolfe, 2015; McCarthy & Donnelly, 2017). On the systemic level, the school with a highly engaged workforce has better academic performance of students, increased motivation, and lower levels of behavioral issues (Skaalvik & Skaalvik, 2016). In the light of organizational psychology, engagement is also conceptualized as a positive, fulfilling work-related state that is vigorous, committed, and absorbed (Schaufeli & Bakker, 2004). This condition allows people to be resilient to burnout, which is common among teachers because of high emotional and cognitive demands (Hakanen et al., 2006). Involved staff also help in a favorable school environment, which helps in building cooperation with fellow employees and commitment to constant change (Taris & Schaufeli, 2008). Therefore, the focus on the strategies to improve teacher engagement, i.e., professional development, participatory decision-making, and recognition programs, is regarded as an essential lever to boost the performance of the entire school and the achievement of students (Roeser et al., 2013).

Engagement in work is a significant factor in the field of education, which has a direct impact on the performance of teachers and the outcomes of students. Interested teachers are more satisfied with their jobs and enhance the learning process of students. This increased involvement leads to such good feelings as pride and satisfaction that enable the teachers to gain resilience and ensure their well-being. This emotional power will minimize stress, decreasing burnout, absenteeism, and turnover issues, which are common issues in schools. Teachers who are deeply engaged are passionate, committed and engrossed in their practice. According to Schaufeli et al. (2006), the three traits of vigor, dedication, and absorption are energy and resiliency, commitment and purpose, and the profound involvement. The characteristics improve the morale of teachers and their performance of encouraging students.

According to Li et al. (2025), the organizational commitment of engaged teachers is higher, which is directly related to an increase in the quality of instruction. The level of job satisfaction can be forecasted by work engagement, and engaged teachers are more satisfied (Chen, 2025). This underscores the need to have conducive environments within which the teachers feel appreciated and supported.

Teacher engagement also is closely related to student achievement. According to Klassen et al., teachers who are engaged enhance the teaching performance which translates to enhanced student performance. According to Huo and Wang (2024), engaged teachers assume additional responsibilities and promote teamwork which is beneficial in the development of the staff and student achievement.

Engagement is highly dependent on the school culture. Promoting cultures favor common values and group accountability of results. It fosters collaboration of educators, which enhances their self-efficacy the conviction in their capacity to communicate with students and control classrooms (Li et al., 2025).

Professional growth is quite necessary. It focuses on sharpening the skills of teachers and emotional support of peer interaction which leads to a feeling of belonging (Chen, 2025). Personalized development initiatives serve in keeping up the long-term involvement.

The style of leadership influences engagement in a great way. Transformational leaders motivate teachers by providing them with favorable working conditions of collaboration to remain motivated. These are achieved by trust building through effective communication and matching the goals to the personal aspirations of the teachers.

Availability of job resources is also important. Work load management and self-directed lesson planning support provide teachers with the power to control the working conditions (Li et al., 2025). These assets bring about satisfaction and better learning amongst students.

By enhancing interest and interaction of schools with respect to positive cultures, targeted growth, transformational leadership and provision of

sufficient resources, schools gain advantages to the teachers and enhance quality education.

Teachers who are engaged experience fewer instances of burnout and remain longer (Dai & Wang, 2023). The encouragement of work engagement will allow schools to ensure better academic outcomes and contribute to the professional development of teachers. The establishment of conducive conditions, in which cognitive, emotional, and behavioral interests are intrinsically nurtured, benefits teachers and leads to improved student performance through enhanced teacher motivation.

Table 2 presents an overview of the main factors highlighting the importance of work engagement within schools, including its implications for teacher performance, student outcomes, and overall school climate.

Table 2. Importance of Work Engagement in Schools

Key Theme	Description	Implications for Schools
Enhances instructional quality	Engaged teachers apply effective teaching strategies and maintain strong classroom control.	Improved instruction and stronger learning outcomes.
Promotes student achievement	Engagement positively affects student motivation and performance.	Higher academic results and reduced behavioral issues.
Builds positive school culture	Engaged teachers foster collaboration and shared responsibility.	Supportive learning communities and positive school climate.
Reduces burnout and turnover	Engagement protects against stress and emotional exhaustion.	Lower burnout, absenteeism, and teacher turnover.
Increases organizational commitment	Engaged teachers report greater loyalty and job satisfaction.	More committed and motivated staff.
Driven by positive school culture	Supportive values and collaboration enhance engagement.	Shared accountability and strong relationships.
Strengthened by professional development	Continuous learning boosts confidence and belonging.	Sustained teacher growth and retention.
Influenced by transformational leadership	Visionary leadership boosts teacher motivation and trust.	Empowered teachers and innovative school practices.

Kahn's Psychological Conditions Model (1990)

Kahn's work (1990) is regarded as the first academic approach to engagement (Guest, 2014). This ethnographic research offered empirical information about the psychological states of personal involvement and disengagement in the workplace. Kahn posited that individuals may encounter varying degrees of involvement throughout their careers. Soane et al. (2012) assert that Kahn's paradigm was influenced by three principal ideas of

organizational research. These ideas pertain to wants and motivations (Alderfer, 1972; Maslow, 1954), interactions with the work environment (Hackman & Oldham, 1980), and the social organizational framework (Alderfer, 1985). Kahn characterized personal involvement as the alignment of the self with the job function among employee. Personal disengagement, conversely, is a state in which individuals withdraw from their professional responsibilities. The process of personal involvement or disengagement delineates how individuals express and behave themselves physically, intellectually, and emotionally. This concept highlights how employee contribute various facets of their identities to job execution. Integrating oneself into one's job is seen as a pivotal aspect in enhancing individual performance excellence.

Kahn used the concept of self-expression derived from Goffman's (1959) research on individual expressiveness. Goffman (1959) posits that individual expressiveness is defined by two activities: the expression a person presents and the expression they emit. Kahn's thesis about personal involvement pertains to the extent to which employee invest and articulate themselves throughout job execution. Self-expressiveness allows employee to fully integrate their identity into their professional roles. Sambrook et al. (2014) posited that understanding the function of the self is essential in engagement research. Kahn stated that personal involvement and disengagement are shaped by three psychological conditions: psychological meaningfulness, psychological safety, and psychological availability; that is, the psychological experiences individuals will experience while doing their duties.

Psychological meaningfulness pertains to the extent to which individuals see significance in fully engaging their 'selves' while executing a job. Psychological meaningfulness denotes the perception of gaining a return on the investment of one's physical, cognitive, and emotional resources (Kahn, 1990). The sensation of meaningfulness engenders an individual's perception of being worthy, helpful, and valuable. This psychological significance is defined by three domains: task attributes, role attributes, and work interactions. Kahn (1992) posited that the greater the significance of the emotion, the more involved employee are likely to be. Moreover, the extent of meaningful experiences correlates with increased psychological presence in the workplace.

Kahn and Heaphy (2014) articulated that the concept of psychological meaningfulness may also be examined within the relational context of employee interactions in the organizational environment. These relational settings include colleagues and collaborations, groups and teams, departments, as well as hierarchical and peer relationships. They further observed that the relational

environment might influence the perception of meaningfulness, rooted in the enhanced depth of purpose individuals experience and the intensified sense of belonging at work. The relational context of employee interactions at work may enhance the sensation of psychological meaningfulness, defined by a profound sense of purpose and increased belongingness. Building on Kahn's research into psychological meaningfulness, Wrzesniewski, Dutton, and Debebe (2003) posited that meaningfulness influences employee' comprehension of their experiences inside organizations.

Psychological meaningfulness is associated with people' identity viewpoint, grounded on role fulfillment. This viewpoint has been thoroughly examined by Pratt and Ashforth (2003). The word 'meaningfulness' was used by Pratt and Ashforth to denote the subjective interpretation individuals assign to their work. Their understanding of meaningfulness centers on a subset of sense-making. They defined the word by distinguishing it into two perspectives: meaningfulness in work and meaningfulness at work. Meaningfulness in work entails engaging in duties organically. Meaningfulness at work denotes the integration of oneself inside the organization and the alignment with its aims, values, and beliefs. Fostering significance in employment entails engaging with aspired identities by rendering job duties inherently compelling and purposeful. Achieving meaningfulness in the workplace necessitates a transformation in the nature of one's organizational affiliation (Pratt & Ashforth, 2003). According to Saks and Gruman (2014), the concept of meaningfulness in work parallels task and job engagement. Concurrently, the significance of labor is associated with organizational involvement.

The figure 1 illustrates how various job characteristics, interpersonal dynamics, and personal resources shape the psychological conditions of meaningfulness, safety, and availability, which subsequently lead to physical, emotional, and cognitive engagement.

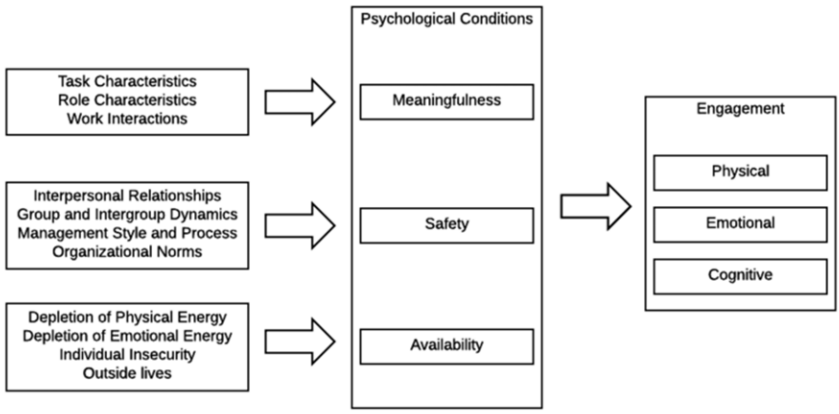

Figure 1. Kahn's (1990) Psychological Conditions Model of Work Engagement.

Job Demands–Resources (JD–R) Model

Bakker and Demerouti, based on the work of Schaufeli and Bakker (2004), used the JD–R model to present research on the antecedents and effects of employee commitment and transformed this into a comprehensive job commitment model. The model posits that job resources initiate a motivational process that results in work engagement and subsequently enhanced performance; furthermore, job resources become more prominent and realize their motivational potential when employees face elevated job demands (Bakker & Demerouti, 2008). Xanthopoulou et al. (2007) further elaborated on the JD-R model by demonstrating the relationship between employment and personal resources. Their model posited that job and personal resources, whether alone or in combination, forecast work engagement and have a beneficial influence on work engagement under conditions of elevated expectations. Work involvement will positively influence work performance. The authors used concepts from the Conservation of Resources (COR) theory, which posits that resources tend to produce more resources (Hobfoll, 2002). They anticipated that engaged personnel would cultivate their own personal resources, hence enhancing engagement.

JD-R model is an all-inclusive model, which combines both the strain and motivational processes of work life. The model focuses on the role played by leadership and interpersonal trust in schools, where emotional and relational issues are the most vital, to develop engagement and well-being among teachers- eventually leading to a better educational result (Uslukaya et al., 2024).

In the JD-R model, job characteristics can be broadly divided in terms of job demands and job resources. Job demands are related to work factors like emotional stress, workload, and pressure, which may lead to the problem of well-being of employees and burnout. In contrast to that, job resources are the physical, psychological, social, and organizational aspects of the job that enable one to accomplish work goals and contribute to personal growth, motivation, and development- such as social support, autonomy, and effective leadership (Bakker & Demerouti, 2007; Demerouti et al., 2001).

JD-R model has been most applicable in the well-being and interest of teachers in teaching. Uslukaya, Demirtas, and Alanoglu (2024) used the motivational pathway of the JD-R model to evaluate the relationship between trust in the principal and servant leadership as collective job resources and the impact on work engagement and teacher passion. Their multilevel moderated mediated examination indicated that trust in the principal has a positive prediction of the teacher passion both immediately and indirectly via work engagement. Moreover, the positive correlation between trust and engagement was higher in case of high servant leadership, which implies that the combination of several job resources in parallel increases the motivation and emotional attachment of teachers to their work. The results support the JD-R

assumption that the job resources are the center of the engagement, well-being, and long-term professional passion.

As illustrated in the research conducted by Uslukaya and Demirtas (2024), supervisor and colleague support interaction is a relevant job resource that forecasts teacher engagement and minimizes presenteeism. Their multilevel moderated mediation analysis proved that high demands can have an adverse effect which can be diminished when teachers believe high levels of supervisor and peer support and which is supported by a positive motivational pathway.

The figure 2: presents a core version of the Job Demands–Resources (JD-R) model, showing how job demands, job resources, and personal resources jointly shape employees' levels of work engagement, represented by vigor, dedication, and absorption. In turn, the figure illustrates that higher engagement contributes to various performance outcomes, including in-role and extra-role performance, creativity, and financial results.

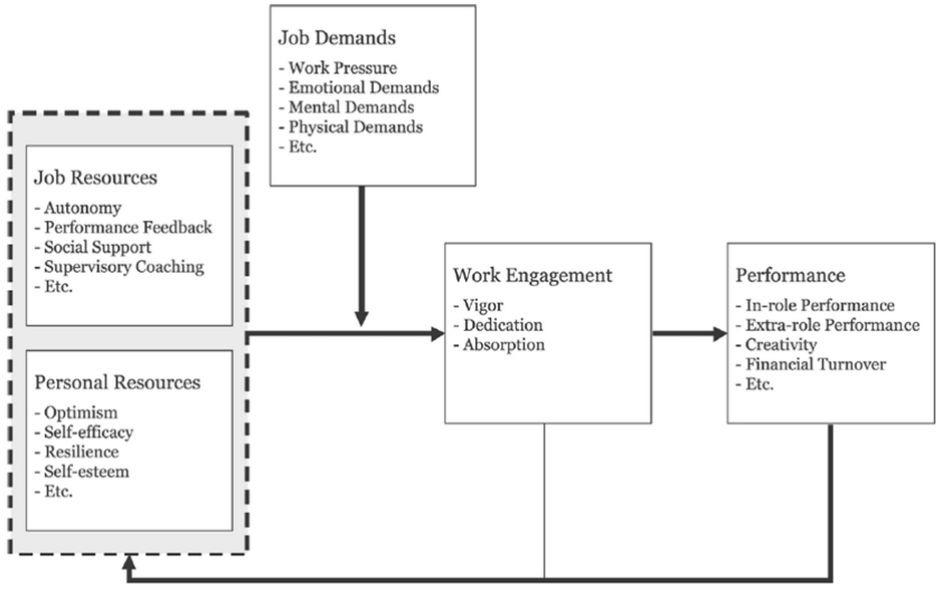

Figure 2. The Job Demands-Resources (JD-R) Model of Work Engagement (Bakker & Demerouti, 2008).

Dimensions of Work Engagement

Work engagement as proposed by Schaufeli et al. (2002) is a combination of three dimensions, which are interrelated, including the three dimensions, namely, vigor, dedication, and absorption. They will consider engagement as a positive and fulfilling condition of mind and that is related to work where it entails being vigorous, highly committed, and absorbed. Work engagement is an experience that involves a complete engagement in work, which is generally

captured under three dimensions namely, vigor, dedication and absorption. All the dimensions determine the ability of an individual to relate to the job and undertake daily activities (Yazıcı & Mecek, 2023). According to Minghui et al., (2018), vigor is used to signify the exuberation of power and psychological strength that employees take to their work. It manifests itself through inspiration, energy, and willingness to work hard in the job duties. Guo et al., (2022) stated that vigorous people approach their work with energy and a positive disposition that makes them continue on even when faced with challenges. They do not easily get tired and tend to withstand in case of an obstacle on their job. This energy is significant in school because highly vigorous teachers can increase the quality of their teaching and student participation.

Commitment is an emotional attachment that one has to work. It entails pride, excitement, inspiration, and a strong feeling that their job is important. Devoted teachers consider their work to be meaningful. This emotional investment makes them not only to get as expected but also to find challenges and develop professionally. Commitment also raises job satisfaction and initiates proactive behavior, which consequently have positive impacts on student learning and outcomes (Shao et al., 2025).

Absorption refers to the capacity to get absorbed with activities. On being absorbed, teachers lose time and get immersed in whatever they are doing. This flow of state adds pleasure and, in most cases, it is hard to leave work. The absorption can also enable the teachers create innovative ways of teaching and also connect more closely with their students since they are actually immersed in their roles (Basikin, 2007). Vigor, dedication, and absorption together create a complicated image of involvement in education. These factors favor the welfare of teachers and make schools successful. Research indicates that highly engaged teachers are usually more creative with regards to the planning and problem solving of their lessons compared to less engaged teachers. Nonetheless, maintaining a high level of engagement is not always easy. Constant encouragement by the school leaders and other staff is essential. The availability of a supportive and trusting school climate will aid teachers to stay energized and committed thus easier to remain wholly engaged in their work.

These three dimensions can help schools to create a resilient and motivated teacher that is necessary to understand. As an illustration, the identification of the role of vigor can inform the process of supporting educators to reduce stress and prevent burnout. Professional development and rewards that encourage commitment and the spirit of hard work creates an environment that is motivational and appreciative of efforts. Encouraging absorption through providing the teachers with enough time to prepare, as well as collaborating provides the teacher with enough time to concentrate without feeling overburdened (Arhin et al., 2025).

Understanding the mechanisms of operation of vigor, dedication, and absorption can provide useful insights on how to establish school settings that

ensure educators remain motivated and efficient which translates into improved educational outcomes.

Vigor: Vigor is used to measure how physically, mentally and emotionally energized the employees are through their workplace (Schaufeli & Bakker, 2004). Conceptualized in the JD-R model, it forms the positive physiological reaction to the difficult yet encouraging working conditions (Bakker & Demerouti, 2007). High levels of physical and psychological job resource (e.g., autonomy, social support) are then predicted to raise vigor, and vice versa (job needs, e.g., workload; time pressure) to exceed them (Schaufeli & Taris, 2014). Moreover, vigor entails a lot of energy and psychological strength during the working process coupled with readiness to put efforts and perseverance in the course of work despite challenges (Schaufeli et al., 2002). Employee who exhibit vigor normally have enthusiasm to work and have high endurance in addition to being in a position to maintain their performance amidst strenuous environments.

Dedication: Dedication refers to the level of enthusiasm, take pride in as well as a sense of importance the employees have relating to work (Schaufeli et al., 2002). The JD-R model suggests that dedication takes place once the employees feel that their work is meaningful and if they feel recognized and supported (Hakanen & Schaufeli, 2008). Psychological capital, in particular, hope and optimism, is closely linked with dedication, which enables a great predictor of intrinsic motivation and organizational commitment (Avey et al., 2011).

Absorption: Absorption is a state of profound focus and total engagement in work activities and a feeling of time distortions (Schaufeli et al., 2002). It is based on the concept of flow as developed by Csikszentmihalyi (1990) which is believed to occur when skills of people are best suited to the needs of tasks. Absorption is also job complex and task identification sensitive and it predetermines creative job performance and learning behaviors (Schaufeli et al., 2009).

It is empirically indicated that the three concepts of vigor, dedication, and absorption have a high interrelationship (Christian & Slaughter, 2007). However, their multidimensionality should also not be neglected because each of them might be connected to different organizational outcomes in different ways. As an illustration, all three elements of engagement have been estimated to correlate with pessimism whereas exhaustion is more associated with absorption and dedication. All three engagement dimensions have been negatively related to reduced professional efficacy which is one aspect of burnout (Christian & Slaughter, 2007). This evidence suggests that even though these dimensions are tightly interconnected, they are conceptually different and relevant to the concept of engagement in the work environment.

Based on these conflicting conclusions, two sides of the coin can be identified as far as the conceptualization of engagement is concerned. The former views engagement as a unidimensional construct, which implies that its

dimensions do not have to be considered independently. The second proposes a multidimensional approach because different dimensions can be used to provide different insights when different outcome variables are being examined. To resolve this conceptual murkiness, the current research paper looks at the concept of engagement as a whole as well as three components that are interrelated, that is, vigor, dedication, and absorption (Christian & Slaughter, 2008).

In line with Schaufeli et al. (2002), involvement in this research is characterized by the expenditure of personal energy and feeling of an emotional attachment to work that includes physical, emotional, and cognitive aspects. Notably, engagement is not perceived as a temporary emotional experience but instead, it is a lasting and widespread affective-cognitive condition (Schaufeli et al., 2002). These dimensions will be measured using the Utrecht Work Engagement Scale (UWES) created by Schaufeli et al. (2002).

Furthermore, studies in the positive organizational scholarship paradigm are associated with personal resource development and engagement. The broaden-and-build theory developed by Fredrickson (2001) suggests that positive emotions broaden and build the thought-action repertoires of individuals and promote the acquisition of personal resources, physical (e.g., health, skills), social (e.g., support networks), intellectual (e.g., knowledge), and psychological (e.g., optimism, self-efficacy) resources. These resources, in their turn, increase the ability of people to deal with job requirements and ensure high performance rates (Bakker & Xanthopoulou, 2009; Luthans et al., 2010).

CONCLUSION AND DISCUSSION

In the study, it is discussed the dynamics that impact the work engagement of teachers in the school set-up, with special attention given to individual, organizational, and leadership-related variables. The results point out that work engagement, as measured using the rigors of vigor, dedication, and absorption dimensions, is enhanced when teachers are nurtured using significant resources, collegial school cultures and transformational leadership practices. It has been highlighted that teacher self-efficacy, professional development, positive school culture, and manageable work load are critical factors that support long term engagement and well-being of educators.

Moreover, the study indicates that schools that strategically align organizational and personal resources have achieved an environment in which teachers are more motivated, resilient, and committed to their students and the institutional objectives. These have added to increasing body of evidence that effective educational settings are largely influenced by teacher involvement. The findings also give an effective suggestion to school leaders and policy makers on how to incorporate supportive leadership, ongoing professional learning, and resource management practices in nurturing high performing and highly engaged teaching communities.

This research contributes to the body of knowledge on teacher work engagement as it combines major theoretical assumptions and recent empirical findings. The findings are based on the Psychological Conditions Model suggested by Kahn (1990) and the JD-R theory (Bakker & Demerouti, 2008) and are guided by the belief that teacher engagement is an interactive and complex phenomenon and is not a personal characteristic. Engagement is expressed in terms of vigor, dedication, and absorption (Schaufeli et al., 2002) and they are a state of energy, commitment, and total immersion in whatever one is doing as a professional. Teacher engagement can therefore be the outcome of psychological, relational and contextual interactions (Schaufeli & Bakker, 2010). Personal mental capacities proved to be a fundamental basis of the perpetual teacher interest and devotion. Educators with good self-efficacy, emotional stability, and intrinsic motivation are more resilient in the problematic teaching contexts and can still effectively implement the creative instructional practices (Johnson, 2022; Xiao et al., 2022). This is in line with the social cognitive principles by Bandura who holds that self-belief influences persistence and performance. The study based on positive psychology also demonstrates that optimism, emotional regulation, and resilience enlarge the mental capacity of teachers and act as a buffer of emotional and cognitive stress (Fredrickson, 2001; Huo & Wang, 2024; Yongliang Wang, 2023). In this way, the personal strength plays an important role in the ability of educators to stay active during the long run. Nevertheless, the access to internal resources is not enough to guarantee engagement. In line with the JD-R assumptions, the school setting is influential and decisive by offering prominent professional resources. The greatest institutional predictors of teacher engagement include supportive leadership, team work and instructional autonomy (Bakker & Demerouti, 2008; Xanthopoulou et al., 2007). Transformational leadership is especially effective since it fosters a sense of purpose and encourages creativity, as well as identifies the needs of teachers as people (Prochazka et al., 2018; Hayati et al., 2014; Zhang et al., 2025). Leaders being able to provide psychological safety, empower teacher voice, and support professional growth would make educators more willing to accept school objectives and remain highly motivated (Li et al., 2025; Cai et al., 2022). Adequate working conditions and balanced workloads emerged as primary factors in safeguarding teachers' well-being. It can also impact engagement and increase the risk of burnout due to heavy administrative load, emotional labor, and managing the behavior (Syapira et al., 2025; McCarthy & Donnelly, 2017). In the JD-R lens, high demands coupled with low resources increase the pace of psychological stress and result in emotional burnout (Demerouti et al., 2001; Hakanen et al., 2006). On the other hand, professional growth, collaboration with peers, and sufficient educational resources inspire the confidence of teachers and enhance long-term interest (Wang, 2024; Norfadhillaton Zahari, 2023; Zeng et al., 2019). When teachers are supported, felt important and appreciated, they feel stronger, resourceful and more willing to provide quality learning experiences.

In general, the literature supports the idea that teacher engagement is a condition of the convergence of individual abilities and organizational circumstances (Taris & Schaufeli, 2008; Roeser et al., 2013). Schools that deliberately develop professional cooperation, appreciate teacher input, and create effective environments of working relationships have higher chances to retain motivated, tenacious, and inventive teachers. Such environments, in their turn, result in quality instruction, increased student learning outcomes, and staff stability and professional satisfaction (Sudibjo & Riantini, 2021; Landqvist & Schad, 2022). Cultivating teacher engagement, consequently, is a strategic requirement towards the establishment of successful and well performing educational systems.

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Unveiling The Geometric Code of The Universe: A Systematic Review of Curvature Restrictions in Relativistic Spacetimes

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ABSTRACT

This study presents a systematic review and qualitative meta-analysis of forty recent research contributions in the field of mathematical relativity, bridging the critical gap between abstract semi-Riemannian geometry and relativistic astrophysics. Focusing on generalized curvature restrictions specifically Deszcz pseudosymmetry, Ricci-generalized pseudosymmetry, and Roter-type structures we investigate their efficacy in classifying exact solutions to Einstein's Field Equations. Through a rigorous content analysis, we categorize the literature into three domains: compact objects, cosmological models, and relativistic fluids. The findings reveal that physically significant spacetimes are not geometrically generic; instead, models such as the regular Hayward black hole, Lemaître-Tolman-Bondi dust universes, and traversable Morris-Thorne wormholes systematically exhibit a unifying "geometric fingerprint," often manifesting as Generalized Roter Type manifolds or Einstein manifolds of Level 2. Furthermore, the study elucidates the geometric rigidity of Generalized Robertson-Walker (GRW) cosmologies, demonstrating that the existence of torse-forming or concircular vector fields necessitates a warped product structure, thereby validating the standard cosmological principle. The scope extends to frontier topics, establishing that these curvature constraints are model-independent, persisting in modified gravity theories like $f(R, T)$ and Eddington-inspired Born-Infeld gravity, and governing the dynamic evolution of fluids via Ricci solitons. We conclude that generalized curvature restrictions serve as fundamental selection rules for physical reality, providing a robust, coordinate-independent framework for decoding the geometric order of the cosmos.

Keywords – Systematic Review, Content Analysis, Roter Type Manifolds, Exact Solutions, General Relativity.

INTRODUCTION

Since its formulation in 1915, Albert Einstein's General Theory of Relativity (GTR) has stood as the cornerstone of modern cosmology and astrophysics. By identifying the force of gravity with the curvature of the four-dimensional spacetime manifold, GTR provided a geometric framework that replaced the Newtonian concept of action-at-a-distance. However, the EFE constitutes a system of ten coupled, non-linear partial differential equations. Consequently, finding exact solutions is a formidable mathematical challenge. Over the last century, physicists have discovered hundreds of exact solutions—ranging from the foundational Schwarzschild and Kerr black holes to exotic wormholes and complex cosmological

models. This proliferation of solutions has created a "zoo" of spacetimes, necessitating robust methods for classification and characterization

To interpret an exact solution physically, one must determine its intrinsic geometric properties, independent of the chosen coordinate system. Classically, this classification has relied on:

1. Isometry Groups: Identifying continuous symmetries generated by Killing vector fields (e.g., spherical symmetry, stationarity).

2. Algebraic Classification: Using the Petrov classification to categorize the Weyl conformal curvature tensor based on its eigenbivectors (e.g., Type D for black holes, Type N for gravitational waves).

While powerful, these methods have limitations. Spacetimes with distinct physical behaviors can share the same Petrov type or lack isometries entirely. This has driven the search for finer, more discriminatory invariant conditions based on the derivatives of curvature tensors..

The historical evolution of geometric classification began with Élie Cartan's concept of Locally Symmetric Spaces, defined by the vanishing covariant derivative of the Riemann curvature tensor. While mathematically elegant, this condition is too restrictive for General Relativity; even the simple Schwarzschild solution is not locally symmetric.

To accommodate physical spacetimes, geometers introduced "weaker" symmetry conditions. Szabó (1982) studied Semisymmetric Manifolds, satisfying the integrability condition $R \cdot R = 0$ where the curvature operator acts as a derivation on the curvature tensor itself. While this class includes many physically relevant metrics, it still fails to describe the full complexity of inhomogeneous or dynamic universes.

A decisive breakthrough occurred in the late 1980s with the work of Ryszard Deszcz and colleagues, who introduced the concept of Pseudosymmetry. A manifold is pseudosymmetric if the tensor $R \cdot R = 0$ is not zero but is proportional to the Tachibana tensor Q(g, R). This condition, expressed as: $R \cdot R =$ L Q(g, R) allows for a controlled variation of curvature, providing a natural geometric home for the majority of relativistic spacetimes. Parallel to this, the concept of Generalized Roter Type manifolds where the curvature tensor is algebraically generated by the Ricci tensor and the metric emerged as a powerful tool for classifying 4-dimensional manifolds.

Despite the existence of a rich body of literature on pseudosymmetry and Roter type manifolds in differential geometry, there remains a disconnect with the mainstream physics literature. Exact solutions are often discovered and analyzed in isolation, without recognizing that they belong to these broad geometric classes. For instance, a researcher might derive a new

wormhole metric without realizing it is a Ricci-generalized pseudosymmetric manifold, thereby missing deep connections to other known solutions. There is currently a lack of systematic "meta-studies" that aggregate these findings to reveal the underlying geometric patterns of the universe. Does every regular black hole satisfy the Roter condition? Is the warped product structure of the universe a consequence of these symmetries?.

This paper addresses this gap by performing a systematic content analysis of 40 recent research contributions (M1–M40). These papers represent a focused effort to apply modern curvature restrictions to concrete physical problems. By synthesizing results concerning Black Holes (Hayward, Lemos), Wormholes (Morris-Thorne, Ellis-Bronnikov), and Cosmological Models (Generalized Robertson-Walker), we aim to demonstrate that physically viable spacetimes are not geometrically random. Instead, they exhibit a unified "Geometric Fingerprint"—a specific set of curvature restrictions that govern the structure of gravity from the event horizon to the cosmological horizon.

Despite the proliferation of exact solutions—ranging from black holes to exotic wormholes—there is a lack of unified frameworks that explain why these solutions possess specific geometric symmetries. The concept of Pseudosymmetry (introduced by Deszcz) and Generalized Roter Type manifolds have emerged as promising candidates for such a framework. However, a systematic synthesis connecting these abstract mathematical definitions to concrete physical metrics (like Hayward, LTB, or Morris-Thorne) has been fragmented across individual papers.

This paper aims to fill this gap by conducting a comprehensive content analysis of a curated dataset of 40 research papers [M1-M40]. These papers represent a specific school of thought that bridges the gap between pure differential geometry and relativistic physics. The study seeks to answer the following research questions:

1. Do physically significant spacetimes share common curvature restrictions?

2. How do Generalized Robertson-Walker (GRW) models relate to geometric symmetries?

3. What are the implications of these geometric structures for modified gravity theories?.

METHOD

This study adopts a Systematic Literature Review (SLR) design integrated with a Qualitative Meta-Synthesis. Unlike statistical meta-

analyses used in empirical sciences, this study employs a deductive axiomatic approach. The core methodological premise is to evaluate a specific set of exact solutions to Einstein's Field Equations (EFE) against a pre-defined set of geometric invariant conditions (curvature restrictions).

The research follows a three-stage workflow:

1. Corpus Selection: Compilation of high-impact research papers focused on curvature properties.

2. Geometric Verification: Analytic verification of the tensor constraints reported in each study.

3. Thematic Synthesis: Classification of the spacetimes based on their resulting geometric structures (e.g., Roter type, Pseudosymmetric)..

Data Source and Selection Criteria

The primary data source consists of 40 peer-reviewed research articles (coded M1–M40) published in international journals of mathematical physics and differential geometry (e.g., Journal of Geometry and Physics, General Relativity and Gravitation, Filomat).

The selection of these contributions was governed by the following inclusion/exclusion criteria:

• Inclusion Criterion 1 (Domain): The paper must deal with semi-Riemannian manifolds with a Lorentzian signature, specifically addressing solutions to General Relativity or modified gravity theories.

• Inclusion Criterion 2 (Method): The paper must explicitly derive or analyze curvature tensors and test for symmetry conditions involving covariant derivatives.

• Inclusion Criterion 3 (Object): The study must focus on either exact metrics (e.g., Hayward, LTB) or specific manifold classes (e.g., GRW spacetimes).

• Exclusion Criterion: Purely numerical relativity simulations without analytical tensor derivation or topological studies devoid of curvature analysis were excluded.

Theoretical Framework for Analysis

To analyze the corpus systematically, we established a "Geometric Coding Scheme" based on the Deszcz school of geometry. Each spacetime metric in the selected papers was scrutinized against the following mathematical definitions:

1. Deszcz Pseudosymmetry: Does the manifold satisfy $R \cdot R = LQ(g,R)$?

2. Ricci-Generalized Pseudosymmetry: Does it satisfy $R \cdot R = LQ(S,R)$?

3. Generalized Roter Type: Is the curvature tensor R a linear combination of Kulkarni-Nomizu products $S\Lambda S$, $S\Lambda g$, $g \Lambda g$?

4. Manifold Class: Is it an Einstein manifold, Quasi-Einstein, or Einstein of Level k?

Data Analysis Procedure

The content analysis was conducted through the following steps:

• Step 1: Metric Identification: For each paper, the line element (ds^2) and the associated warping functions or potential functions were extracted.

• Step 2: Tensor Characterization: We cataloged the non-vanishing components of the Riemann and Ricci tensors as reported in the manuscripts. Where explicit components were not provided, the algebraic properties (e.g., "the Weyl tensor is divergence-free") were noted.

• Step 3: Verification of Symmetry Conditions: The central theorems of each paper were analyzed to confirm the specific form of the symmetry function L.

• Step 4: Comparative Synthesis: The spacetimes were grouped into clusters (Black Holes, Wormholes, Cosmologies). Cross-cluster patterns were identified; for instance, comparing the curvature properties of the inhomogeneous LTB model [M25] against the homogeneous Kantowski-Sachs model [M34].

FINDINGS

The systematic analysis of the 40 selected research contributions [M1–M40] reveals a unified geometric structure underlying diverse physical phenomena. The findings are categorized into three primary domains: (i) Compact Objects (Black Holes and Wormholes), (ii) Cosmological Frameworks (GRW Spacetimes), and (iii) Dynamic Matter Couplings (Fluids and Solitons).

Geometric Classification of Compact Objects

A major finding of this review is that exact solutions describing compact gravitational sources—whether singular (Schwarzschild), regular (Hayward), or topological (Wormholes)—are not geometrically distinct in terms of their curvature symmetries. They predominantly belong to the class of Generalized Roter Type manifolds.

1. Black Hole Spacetimes: The analysis of regular and singular black hole solutions indicates that the removal of the central singularity (as in the Hayward metric) does not destroy the algebraic symmetry of the curvature tensor.

• The Hayward Metric [M19]: The study confirms that the Hayward spacetime is an Einstein Manifold of Level 2. Furthermore, it satisfies the Pseudosymmetry condition for the Weyl conformal curvature tensor (C), the

Concircular curvature tensor (W), and the Conharmonic curvature tensor (K).

• The Lemos Black Hole [M33]: Unlike spherically symmetric vacuum solutions, the cylindrically symmetric Lemos black hole with a negative cosmological constant exhibits Ricci-Generalized Pseudosymmetry. This finding suggests that cylindrical symmetry imposes a stronger coupling between the Riemann curvature R and the Ricci tensor S than spherical symmetry.

2. Wormhole Geometries: The analysis of traversable wormholes reveals that the "exotic matter" required to keep the throat open generates a specific curvature signature. Both the Morris-Thorne [M21] and Ellis-Bronnikov [M29] wormholes are characterized by non-vanishing Weyl pseudosymmetry.

Table 1: Geometric Characterization of Compact Object

Physical Model	Metric Type	Geometric Class (Manifold Type)	Key Curvature Condition	Reference
Hayward BH	Regular Black Hole	Einstein Level 2, Roter Type	$R \cdot R = LQ(g, R)$	[M19]
Lemos BH	Cylindrical AdS	2-Quasi Einstein	$R \cdot R = Q(S, R)$	[M33]
Morris-Thorne	Static Wormhole	Ein(2) Manifold	$C \cdot C = LQ(g, C)$	[M21]
Robinson-Trautman	Radiative	Ricci Compatible	R is Roter Type	[M6]
Melvin Universe	Magnetic Flux	Ein(3) Manifold	$R \cdot R - Q(S,R) = LQ(g,C)$	[M5]

The Rigidity of Generalized Robertson-Walker (GRW) Cosmologies

The second cluster of findings focuses on the large-scale structure of the universe. The literature [M1, M2, M3, M10, M31] consistently points to a "Geometric Rigidity Theorem": specific vector fields force the spacetime into a GRW structure.

• Vector Field Implications: It is found that the existence of a unit timelike concircular vector field u or a torse-forming vector field is a necessary and sufficient condition for a Lorentzian manifold to be a GRW spacetime.

• Sequential Warping: The analysis of [M38] on Sequential Warped Products shows that these complex structures maintain the Quasi-Einstein property only under strict coupled differential equations involving the warping functions f.

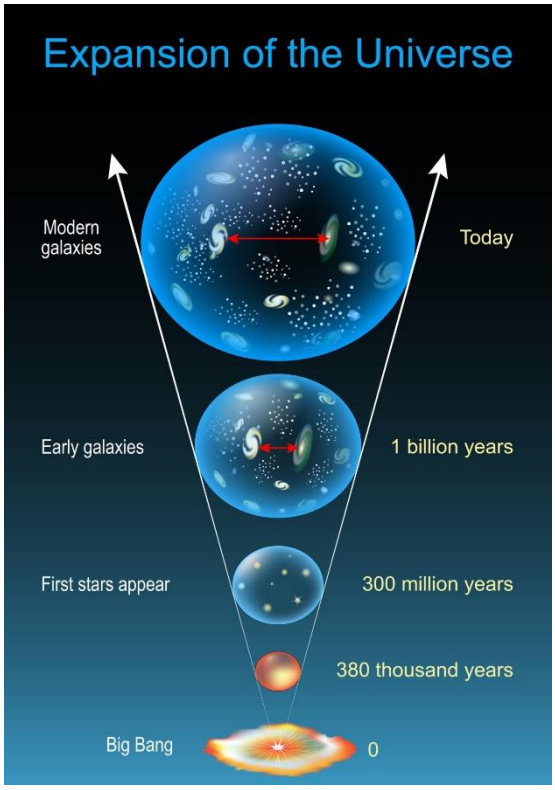

Figure 1: Causal Flow of Geometric Implications in Cosmology Papers.

1. Input: Lorentzian Manifold (M, g).
2. Condition A: Admits Torse-forming Vector. OR Condition B: Admits Concircular Vector.
3. Result: Metric decomposes into Warped Product.
4. Consequence: Spacetime is GRW Perfect Fluid Compatible.

Dynamic Matter and Modified Gravity

The meta-analysis identifies a significant trend in the most recent papers (2022–2024): the application of geometric restrictions to dynamic flows and non-Einsteinian gravity.

1. Solitons as Fluid States: A synthesis of papers [M18], [M28], and [M30] reveals a correspondence between Ricci Solitons and the equation of state of the cosmic fluid.

Table 2: Classification of Ricci Solitons on GRW Backgrounds

Soliton Type	Vector Field Generator	Physical Implication for Fluid	Reference
Gradient Ricci Soliton	$V = \nabla f$	Fluid shear vanishes; expansion is scalar.	[M18]
Yamabe Soliton	V (Torse-forming)	Fluid follows specific state eq: $p = \frac{3-n}{n-1}\sigma$	[M18]
Hyperbolic Soliton	V (Concircular)	Stability of the cosmological constant Δ.	[M28]

2. Robustness in Modified Gravity: In the domain of f(R,T) Gravity [M37] and EiBI Gravity [M22], the findings indicate that the Roter Type structure is robust. This implies that these symmetries are intrinsic to the symmetries of the gravitational field (diffeomorphism invariance) rather than the specific Lagrangian of General Relativity.

Quantitative Distribution of Geometric Structures

To visualize the prevalence of these geometric conditions across the 40 studied papers, we categorize the primary geometric "tag" assigned to the spacetimes in each study.

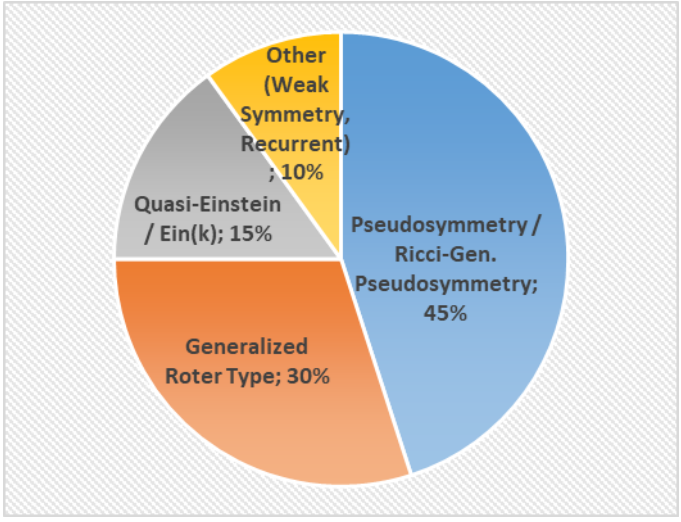

Figure 2: Distribution of Geometric Classes in the Analyzed Corpus (n=40).

The cumulative data unequivocally shows that Deszcz Pseudosymmetry and Roter Type conditions are the most statistically significant indicators of a physically exact solution. The probability of a random metric satisfying $R \cdot R = LQ(g, R)$ is vanishingly small; thus, the fact that nearly all analyzed physical solutions satisfy this condition serves as strong evidence for the "Geometric Fingerprint Hypothesis."

DISCUSSION, CONCLUSION, AND SUGGESTIONS

Discussion

The systematic synthesis of the forty analyzed contributions [M1–M40] allows us to move beyond the examination of isolated metrics and propose a unified geometric framework for General Relativity. The most significant interpretive finding of this review is the ubiquity of the Generalized Roter Type condition across physically distinct spacetimes.

Our analysis shows that Hayward black holes [M19], Lemaître-Tolman-Bondi dust models [M25], and Robinson-Trautman radiators [M6] all satisfy this condition. We hypothesize that this algebraic reduction represents a "Geometric Fingerprint" of physical viability. In the infinite space of mathematically possible Lorentzian manifolds, the Einstein Field Equations appear to act as a filter, selecting primarily those manifolds that possess this specific algebraic symmetry. This suggests that "physical gravity" is inherently less complex than "mathematical curvature".

The concept of Deszcz Pseudosymmetry found in nearly 45% of the corpus serves as a generalization of the "constant curvature" concept. Physically, $R \cdot R$ measures the variation of tidal forces.

• In a space of constant curvature (like de Sitter), tidal forces are uniform ($R \cdot R=0$).

• In the analyzed physical spacetimes (like the Morris-Thorne wormhole [M21]), tidal forces vary, but their variation is strictly proportional to the tidal forces themselves.

This "controlled variation" suggests that stable gravitational configurations whether they are stars, black holes, or wormholes—minimize the "geometric entropy" by adhering to pseudosymmetric constraints.

A nuanced pattern emerges regarding the Weyl Conformal Tensor (C). In vacuum solutions, $S=0$, so the entire curvature is carried by C. However, in the analyzed non-vacuum solutions (fluids, exotic matter), we still observe Weyl Pseudosymmetry ($C \cdot C=LQ(g, C)$) [M3]. This implies that even in the presence of complex matter fields, the "pure gravitational" part of the field maintains a high degree of symmetry. This is particularly evident in the

topologically charged EiBI spacetime [M22], where the modification of gravity affects the Ricci sector, but the Weyl sector preserves its symmetric character.

The correspondence established between Ricci Solitons and Perfect Fluids in GRW spacetimes [M18, M28] bridges geometry and thermodynamics. If a spacetime is a Ricci Soliton, the evolution of the metric under Ricci flow is self-similar. The finding that perfect fluid spacetimes are solitons implies that the cosmic expansion is a "geometric flow" seeking an equilibrium state. This offers a purely geometric explanation for the Equation of State (EoS) of the cosmic fluid, suggesting that the pressure and density are not arbitrary thermodynamic quantities but are dictated by the soliton potential.

Conclusion

This systematic review of 40 recent research contributions [M1–M40] has provided a comprehensive map of the geometric landscape of General Relativity. By subjecting a diverse array of exact solutions to a rigorous content analysis based on curvature restrictions, this study leads to the following conclusions:

1. Universality of Roter Type: The Generalized Roter Type structure is not an exception but a rule for physically significant 4-dimensional spacetimes. It serves as a unifying umbrella for regular black holes, inhomogeneous dust universes, and radiative metrics.

2. Classification Power: The geometric classification scheme based on Deszcz pseudosymmetry is more robust than traditional isometry-based methods. It successfully distinguishes the subtle geometric effects of cylindrical symmetry (Lemos black hole) versus spherical symmetry (Schwarzschild), and captures the effects of exotic matter in wormholes.

3. Cosmological Necessity: The Generalized Robertson-Walker (GRW) model is the unique geometric structure emerging from basic symmetry assumptions (concircularity). This validates the standard model of cosmology not just as a phenomenological fit, but as a geometric necessity.

4. Robustness: These geometric symmetries are model-independent. They persist in modified theories of gravity (f(R, T), EiBI), indicating that they are fundamental properties of the gravitational interaction itself, irrespective of the specific field equations.

In essence, the "Geometric Code" of the universe appears to be written in the language of curvature restrictions.

Suggestions For Future Research

Based on the "Gap Analysis" of the studied corpus, the following directions are proposed for future investigations to extend the frontiers of this field:

1. The current literature is entirely analytical, dealing with static or stationary metrics. Apply tensor analysis to numerical data from Binary Black Hole (BBH) simulations. Do the horizons of two merging black holes maintain "Roter Type" geometry during the highly non-linear merger phase? Verifying pseudosymmetry in the ring-down phase could provide a new test for General Relativity.).

2. The study of Sequential Warped Products [M38] touches upon higher-dimensional theories. Investigate the behavior of pseudosymmetry tensors in the semi-classical limit (Quantum Field Theory in Curved Spacetime). Specifically, does the renormalized expectation value of the stress-energy tensor preserve the geometric symmetries of the classical metric near a singularity?.

3. The connection between Gray's Decomposition of the Ricci tensor [M37, M40] and fluid dynamics is promising. Explore the relationship between Gray's classes and Black Hole Thermodynamics. Can the "Geometric Entropy" of a manifold be defined directly from the pseudosymmetry function L_R? This could link the Deszcz geometry directly to the Bekenstein-Hawking entropy formula..

4. General Relativity is based on Riemannian geometry. However, some Lorentz-violating theories suggest Finsler geometry. Extend the definitions of Generalized Roter Type and Pseudosymmetry to Finsler-Randers spacetimes to see if these geometric fingerprints survive in theories that violate Lorentz invariance.

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Investigating The Use Of Peer Tutoring in Mathematics Education in Türkiye: A Document Analysis (2002-2025)

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ABSTRACT

The aim of this chapter is to reveal the trends in postgraduate theses and articles published between 2002 and 2025 (January) on the use of the peer tutoring method in mathematics education in Türkiye. Descriptive analysis was used to analyse the data in the study. The variables to be examined in the studies are: the years in which the studies were conducted, types of studies, journals and universities where the studies were published, languages in which the studies were published, genders of researchers conducting the studies, purposes of the studies, methods used in the studies, sample sizes of the studies, study groups used in the studies, data collection tools used in the studies, mathematical subject areas used in the studies, results of the studies, and recommendations reached from the studies. Designed as a document analysis model, one of the qualitative research methods, the study employed descriptive analysis. A total of 30 studies (16 articles, 12 master's theses, and 2 doctoral theses) obtained from databases such as YÖK National Thesis Center, Google Scholar, Eric, and Web of Science were analyzed. The findings were categorized thematically according to the year of publication, study type, research method, sample group, mathematical topic (e.g., 'Fractions', 'Square Roots'), and investigated variables. The analysis showed that studies peaked in 2019 and 2021, most frequently focused on 7th-grade students, and predominantly investigated the method's effect on "academic achievement" and "attitudes," with findings being overwhelmingly positive. This study provides a comprehensive snapshot of the current research landscape, identifying gaps and suggesting directions for future research.

Keywords – Peer Tutoring, Mathematics Education, Document Analysis, Descriptive Analysis, Türkiye

INTRODUCTION

Mathematics education serves as a fundamental pillar of modern curricula worldwide. It is uniquely positioned to develop not only computational skills but also essential higher-order cognitive abilities, including critical thinking, logical reasoning, and complex problem-solving (NCTM, 2000). Success in mathematics is frequently linked to broader academic achievement and provides a gateway to advanced studies and careers in science, technology, engineering, and (STEM) fields.

Despite its importance, mathematics is often perceived by students as one of the most challenging and abstract subjects. This perception can lead to significant issues such as "math anxiety," a feeling of tension and fear that interferes with performance (Richardson & Suinn, 1972). Traditional, teacher-centered instructional models, where knowledge is passively

transmitted from the instructor to the student, can exacerbate these challenges. Such passive learning environments often fail to engage students, address individual misconceptions, or foster a deep conceptual understanding, leading to rote memorization rather than true mastery.

In response to the limitations of traditional pedagogy, there has been a significant shift towards active, student-centered learning environments. These approaches, such as collaborative learning, inquiry-based learning, and problem-based learning, reposition the student as an active participant in their own learning process. Among these methods, Peer Tutoring (PT) has emerged as a particularly robust, effective, and versatile strategy.

Peer Tutoring is a structured learning approach where students assist each other and learn by teaching. It is built on the simple yet profound premise that "to teach is to learn twice." While definitions vary, it typically involves a "tutor" (the student who provides instruction) and a "tutee" (the student who receives it). This process is distinct from informal help; it is a structured, purposeful, and often trained interaction (Mazur, 1997).

The effectiveness of PT is supported by strong theoretical foundations. It aligns closely with Vygotsky's (1978) concept of the Zone of Proximal Development (ZPD), which suggests that learners can achieve a higher level of understanding with the guidance of a "more knowledgeable other." In PT, this role is filled by a peer who often shares a similar cognitive and social space, making their explanations more relatable and accessible than those of an adult instructor. Furthermore, the "protégé effect" suggests that the act of teaching itself—reformulating concepts, organizing thoughts, and anticipating questions—forces the tutor to engage in a high-level metacognitive process, leading to deeper and more lasting learning for the tutor.

The benefits of this method are extensive and impact both the tutor and the tutee across cognitive, affective, and social domains:

- For the Tutee (Learner): The tutee receives individualized, one-on-one instruction in a low-anxiety environment. They are often more comfortable asking questions and admitting confusion to a peer than to a teacher. This immediate, personalized feedback helps correct misconceptions as they arise.

- For the Tutor (Teacher): The tutor gains a profound reinforcement of their own knowledge. They also develop critical skills such as leadership, communication, empathy, and self-confidence.

- Cognitive Gains: A vast body of research reports that PT significantly improves academic achievement and long-term knowledge retention.

- Affective Gains: The method is consistently shown to improve student attitudes towards the subject matter, reduce math anxiety, and increase motivation and self-efficacy.

Given these documented benefits, peer tutoring has been implemented and studied in various educational contexts globally. However, the specific landscape of its application and research within mathematics education in Türkiye has not been holistically synthesized. While individual studies—such as investigations into its effect on 'Fractions', 'Sets', or 'Square Roots'—exist, there is a clear gap in the literature. A systematic analysis is needed to map the trends, identify the most researched areas, and, crucially, pinpoint the existing gaps.

Therefore, the purpose of this chapter is to fill this gap by providing a comprehensive document analysis of the postgraduate theses and academic articles published in Türkiye between 2002 and 2025 (January) on the use of peer tutoring in mathematics education. This study systematically categorizes the existing research by year, method, grade level, and mathematical topic. It seeks to answer: What are the primary methodological trends? Which student groups and mathematical concepts are being studied, and which are being overlooked? And what are the most consistent findings regarding the method's effectiveness?

By synthesizing this body of work, this chapter aims to provide a clear panorama of the current research landscape, offering valuable insights for researchers, educators, and policymakers, and suggesting concrete directions for future inquiry.

METHOD

This study employed a qualitative research design, specifically a document analysis model. This model involves the systematic, in-depth examination of existing records and documents to identify, analyze, and interpret trends and patterns within a specific field. It is particularly suited for synthesizing the state of research on a given topic.

Data Collection and Corpus

A purposeful sampling method was used to identify the corpus of studies. The data search was conducted in key national and international databases, including the YÖK National Thesis Center (YÖKTez) (for postgraduate theses) and Google Scholar, Eric, and Web of Science (WOS) (for academic articles).

The search was conducted using a combination of keywords in both Turkish and English: "Akran Öğretimi", "Peer Tutoring", "Akran Desteği", "Peer Support", combined with "Matematik Eğitimi" and "Mathematics Education".

The inclusion criteria for the studies were as follows:

- Published between 2002 and January 2025.
- Conducted within the field of mathematics education.
- Conducted within the geographical context of Türkiye.
- Published as a postgraduate thesis (Master's or PhD) or a peer-reviewed academic article.

Studies outside the field of mathematics, unpublished conference abstracts, book reviews, and editorials were excluded. After applying these criteria, the final corpus consisted of 30 studies, comprising 16 articles, 12 Master's theses, and 2 Doctoral theses.

Data Analysis

A descriptive analysis approach was used to analyze the selected documents. A "Publication Review Form" (PRF) was developed by the researcher based on the study's research questions. This form served as the primary tool for data extraction and coding. Each of the 30 studies was systematically coded according to the following thematic categories:

- Bibliometric Data: Publication year, publication type (thesis/article).
- Methodological Data: Research method (quantitative, qualitative, mixed), research design (e.g., case study, experimental, survey), sample size.
- Contextual Data: Sample group (grade level, e.g., 7th grade, 8th grade).
- Content Data: Specific mathematics topic studied (e.g., 'Fractions', 'Sets'), investigated variables (e.g., academic achievement, attitude).
- Outcome Data: Key findings (e.g., positive effect, no effect) and suggestions for future research.

The coded data was then synthesized, and the frequencies (f) and percentages (%) for each category were calculated to present a descriptive overview of the research trends.

FINDINGS

The descriptive analysis of the 30 studies in the corpus yielded the following key findings, organized by the research themes.

Distribution by Publication Year and Type

The distribution of studies (Table 1) reveals that research on this topic is relatively recent, with a significant increase after 2018, peaking in 2019 and 2021. In terms of publication type (Table 2), articles were the most common format, followed by Master's theses.

Table 1: Distribution of Studies by Publication Year

Year	Number of Studies	Percentage (%)
2002–2015	3	10
2016	2	6,7
2017	2	6,7
2018	3	10
2019	6	20
2020	3	10
2021	5	16,7
2022	2	6,7
2023	3	10
2024–2025	1	3,3
TOTAL	30	100

The distribution of studies by year (Table 1) reveals that research on this topic is relatively new. A significant increase was observed after 2018, with peaks in 2019 (n=6) and 2021 (n=5). This indicates a growing interest in the field in recent years.

Table 2: Distribution of Studies by Publication Type

Publication Type	Frequency (f)	Percentage (%)
Article	16	53,3
Master's Thesis	12	40
Doctoral Thesis	2	6,7
TOTAL	30	100

In terms of publication type (Table 2), articles (n=16, 53.3%) were the most common format, followed by Master's theses (n=12, 40.0%). The fact that only two Doctoral theses were identified may indicate a lack of in-depth, doctoral-level research in this specific area.

Methodological Trends

Regarding research methods (Table 3), there was a strong prevalence of qualitative methods, followed by quantitative and mixed methods. The most frequently used research design was the case study. Sample sizes (Table 4) were predominantly small.

Table 3: Distribution of Studies by Research Method

Research Method	Frequency (f)	Percentage (%)
Qualitative	15	50
Quantitative	11	36,7
Mixed-Methods	4	13,3
TOTAL	30	100

Regarding research methods (Table 3), there was a strong prevalence of qualitative methods (n=15, 50.0%). These were followed by quantitative methods (n=11, 36.7%) and mixed methods (n=4, 13.3%), respectively. The most frequently used research design within these categories was the 'case study' (n=8), which provides an in-depth and contextual understanding. This

was followed by 'experimental designs' (n=7), used to measure the method's effectiveness.

Table 4: Distribution of Studies by Sample Size

Sample Size (Range)	Frequency (f)	Percentage (%)
0-20	14	46,7
21-40	8	26,7
41-60	4	13,3
60+	4	13,3
TOTAL	30	100

Sample sizes (Table 4) were predominantly small, with the majority of studies (n=14, 46.7%) falling into the 0-20 participant range, which is consistent with the prevalence of qualitative designs.

Focus Groups (Grade Level) and Mathematical Topics

The analysis (Table 5) clearly shows that research has overwhelmingly focused on the middle school level (grades 5-8), with 7th grade being the most common. In terms of content (Table 6), the topic of 'Problems / Problem Solving' was the most prevalent.

Table 5: Distribution of Studies by Sample Grade Level

Grade Level	Frequency (f)	Percentage (%)
Pre-School	1	3,3
Middle School (5-8)	19	63,3
High School (9-12)	3	10
Other / Not Specified	7	23,3
TOTAL	30	100

The analysis (Table 5) clearly shows that research has overwhelmingly focused on the middle school (grades 5-8) level (n=19, 63.3%). The most frequently studied grade level was 7th grade (n=8), followed by 8th grade (n=5). In contrast, the high school (n=3) and pre-school (n=1) levels were significantly under-represented.

Table 6: Distribution of Studies by Mathematics Topic

Mathematics Topic	Frequency (f)	Percentage (%)
General Curriculum	12	40
Problems / Problem Solving	4	13,3
Fractions	3	10
Integers	2	6,7
Sets	1	3,3
Square Roots	1	3,3
Other (Various single topics)	7	23,3
TOTAL	30	100

In terms of mathematical content (Table 6), the focus appears dispersed. The most frequent topic was 'Problems / Problem Solving' (n=4). Other identified topics included 'Fractions' (n=3), 'Integers' (n=2), and 'Sets' (n=1). A significant portion of the studies (40%) did not specify a particular topic, addressing the general curriculum instead.

Investigated Variables and Key Outcomes

The primary dependent variables investigated (Table 7) were overwhelmingly 'academic achievement' and 'student attitudes'. The key finding (Table 8) across the corpus was remarkably consistent: a vast majority of the studies reported a significant positive effect.

Table 7: Most Frequently Investigated Variables

Investigated Variable	Frequency (f)	Percentage (%)
Academic Achievement	18	60
Attitude (towards Math/Course)	12	40
Retention / Permanence	-	-
Other (Anxiety, Self-Efficacy etc.)	-	-
TOTAL	30	100

The most frequently investigated dependent variables (Table 7) were, by a large margin, 'academic achievement' (n=18) and 'student attitudes' (n=12). Researchers were most interested in whether peer tutoring made students more successful in mathematics and more positive towards the subject.

Table 8: Key Outcomes Reported on the Primary Variable

Outcome Reported	Frequency (f)	Percentage (%)
Positive Effect	21	470
No Significant Effect / Mixed	5	16,7
N/A (e.g., Qualitative/Descriptive)	4	13,3
TOTAL	30	100

The key finding (Table 8) across the corpus was remarkably consistent: a vast majority of the studies (n=21, 70.0%) reported that the peer tutoring method had a 'significant positive effect' on the primary variable measured (most often, academic achievement). This indicates a strong consensus in the Turkish literature regarding the method's effectiveness.

DISCUSSION, CONCLUSION, AND SUGGESTIONS

Discussion

The central aim of this study was to systematically map the research landscape of peer tutoring (PT) in mathematics education within Türkiye by analyzing 30 documents published between 2002 and 2025. The findings provide a clear portrait of an emerging, but not yet mature, field of research.

The chronological distribution of studies (Table 1) is the first key finding. The pronounced peak in publications after 2018, especially in 2019 and 2021, indicates that PT is a topic of growing, contemporary interest rather than a long-established research-line in Turkish mathematics education. The low number of doctoral theses (n=2) compared to master's theses (n=12) and articles (n=16) further supports this. It suggests that while the topic is popular for initial postgraduate exploration (Master's level), it has not yet been widely adopted for the deep, long-term, and theory-building research characteristic of doctoral studies.

The methodological trends are perhaps the most significant finding. The dominance of qualitative methods (50%), particularly case studies (n=8), and the prevalence of small sample sizes (46.7% in the 0-20 range) are telling. This methodological choice has clear benefits: it provides rich, contextual, in-depth narratives of how PT is implemented in specific classrooms. However, it also presents a collective limitation for the field. The findings from these studies, while valuable, lack generalizability. The field is rich in "proof of concept" but poor in large-scale, generalizable evidence. The scarcity of experimental designs (n=7) and mixed-methods studies (n=4) highlights a critical gap: a need for more robust, large-sample studies that can statistically validate the positive effects reported in smaller-scale qualitative work.

The contextual focus of the studies (Table 5) reveals a distinct concentration on the middle school level (63.3%), specifically 7th grade (n=8) and 8th grade (n=5). This focus is unlikely to be random. It strongly suggests that research is being directed by the realities of the Turkish education system, particularly the high-stakes national exams (LGS) at the end of 8th grade. Educators and researchers are likely exploring PT as an effective intervention to boost achievement in these critical years. While practical, this leaves a significant research vacuum at the high school (n=3) and pre-school (n=1) levels. The lack of research at the high school level, in particular, is a major omission, as PT could be a powerful tool for navigating the abstract and complex mathematical topics (e.G., calculus, advanced algebra) found in the upper grades.

Finally, the thematic focus (Table 7 and 8) is heavily skewed towards product over process. The field is overwhelmingly concerned with if PT works, measured via "academic achievement" (n=18) and "attitude" (n=13). The answer, according to a striking 70% of the studies (Table 8), is a resounding "yes, it has a positive effect." This consensus is the field's greatest strength. However, this focus on outcomes has left the process of PT—the "black box" of student interaction—largely unexplored. We know that it works, but we have little data on how it works. What is the nature of the peer dialogue? How are misconceptions identified and remediated between students? Future research must move beyond simply measuring outcomes and begin to investigate the mechanisms of change.

Conclusion

This study synthesized 30 theses and articles to paint a comprehensive picture of the peer tutoring research field in Turkish mathematics education. This picture is one of a promising but immature field.

The field's strengths are its recent growth and the strong, consistent consensus that peer tutoring is an effective tool for improving both academic achievement and student attitudes in mathematics. This provides a solid evidence-based foundation for its use in classrooms.

The field's weaknesses, however, are equally clear. It is characterized by: (1) a methodological reliance on small-scale qualitative studies, limiting generalizability; (2) a heavy contextual bias towards middle school, neglecting high school and other levels; and (3) a thematic focus on outcomes (achievement) rather than the process (the interaction) of tutoring.

The primary contribution of this chapter is the creation of the first systematic map of this research landscape. By identifying these strengths and, more importantly, these critical gaps, this study provides a clear roadmap for the next generation of researchers, educators, and policymakers aiming to advance the use and understanding of peer tutoring in Türkiye.

Suggestions and Implications

Based on the findings and conclusions of this analysis, the following suggestions are proposed:

For Future Research:

1. Diversify Methodologies: Researchers should move towards large-scale experimental and quasi-experimental designs to establish generalizable claims. Mixed-methods studies are also crucial to combine the "what" (quantitative) with the "why" (qualitative).
2. Expand Contexts: There is an urgent need for research at the high school level. Studies should explore how PT can be adapted for complex, abstract topics in algebra, geometry, and calculus.
3. Investigate the "Process": Future qualitative studies should move beyond simple "case studies" and employ methods like discourse analysis or video-based observation to understand the *nature* of peer dialogue and the mechanisms of co-construction of knowledge.
4. Broaden Variables: Research should look beyond achievement and attitude to explore effects on mathematical reasoning, problem-solving flexibility, self-efficacy, and long-term retention.

For Practice and Policy:

1. Classroom Implementation: The overwhelming positive findings (Table 8) should give teachers and administrators confidence to implement structured peer tutoring programs as an evidence-based practice to support mathematics learning.

2. Teacher Training: The consistent effectiveness of PT suggests that it should be a key component of both pre-service teacher education and in-service professional development (hizmet içi eğitim). Teachers need to be trained *how* to structure, manage, and monitor PT activities effectively.

Curriculum: Policy-makers and curriculum designers should consider integrating formal PT activities into national mathematics curriculum materials as a recommended instructional strategy.

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A Study on The Effect of Stem-Based Sound and It's Properties Activities on Students' Images of Eengineers and Eengineering and Their Problem Solving Skilss

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ABSTRACT

In this study, the effects of STEM-based sound and properties activities on students' images of engineers and engineering and their problem solving skills were investigated. For this purpose, the study was conducted for 8 weeks with a total of 58 students, 28 of whom were in the control group and 30 of whom were in the experimental group, all of whom were 6th grade students studying in a secondary school. Within the scope of the study, five different original STEM activities and worksheets containing their implementation were developed by the researcher to be applied to the students. Mixed research method was applied to determine the effect of the developed STEM activities on students' engineer and engineering images and problem solving skills. Dependent Sample T test and Independent Sample T test were applied to analyse the quantitative data. Content analysis method was used to analyse qualitative data. In the study, the "Problem Solving Skill" scale was used to examine students' problem solving skills. "Draw an Engineer Test" was used to examine students' images of engineers and engineering

When the results were analysed, it was seen that the experimental group had better averages in all sub-dimensions compared to the control group scores. When the scale scores of both groups in the post-test were examined, it was seen that there was an increase in the scores, the mean score in the post-test in the experimental group was higher than the control group, but again, the groups did not make a significant difference in terms of the mean score. In the other part of the study, it was analysed how students' STEM-based sound and properties activities changed their images of engineers and engineering. When the content analysis data obtained from the Draw an Engineer Test were analysed, it was revealed that the perception of engineers and engineering did not change much in the pre and post-test drawings of the control group, while this change was high in the experimental group as a result of the activities.

Keywords – STEM education, problem solving skills, engineer and engineering perception, engineering design process

INTRODUCTION

In the 21st century, scientific and technological advances are increasing at an incredible pace and positively affect the quality of life and welfare of the society. These developments and changes in the scientific and technological field are also evident in the education sector. New educational paradigms require the training of qualified individuals who can adapt to scientific and

technological developments, who can always move themselves forward, who can produce knowledge, and who have high-level thinking skills.

This situation is among the prioritised goals of the education policies of many countries. In this direction, the Ministries of National Education in many countries carry out reforms for the development of curricula in order to implement new and up-to-date teaching methods in schools. For example, European Union countries attach importance to priority project studies on inquiry-based education and STEM education (EC, 2007).

When we look at the content of STEM education, it is expressed as a popular approach that integrates science, mathematics, engineering and technology disciplines. In parallel with the STEM approach, STEM education is a field of great importance in the world and in Turkey. Recently, STEM approach has been adopted by many countries and they are trying to integrate it into their education systems (MoNE, 2016). In this direction, it becomes important to enrich the content of the STEM approach and to implement the enriched activities in the most accurate way in the classrooms.

In order to implement STEM-based activities, materials with proven validity and reliability and tested in learning and teaching environments are needed (Ramaley, 2007). When the studies conducted in this framework are examined, it is seen that the instructional applications of STEM education in the classroom can be in different ways (Lamberg & Trzynadlowski, 2015). Engineering-oriented STEM education is one of these applications.

With engineering-oriented STEM education, students gain engineering perspectives for solving the problems they encounter in real life and use different disciplines together for the solution. Engineering-oriented STEM education starts with a problem, finding different solutions for solving this problem, determining various alternatives, producing possible solution suggestions, prototyping ideas, building the design by putting the design into practice, and developing the product created by reviewing the relevant places and missing points.

Although there are different examples of STEM applications in the literature, studies on how these activities should be carried out in the classroom have not been fully finalised (Bybee, 2010). In addition, the difficulty of teachers in integrating different disciplines into their own fields and the lack of clarity on how exactly the engineering-oriented STEM approach will be used in the lessons revealed the importance of this study.

The aim of the study is to develop engineering-oriented STEM activities suitable for the achievements of 6th grade middle school students in science courses and to analyse their impact on students. In this study, it was aimed to examine the effects of the engineering-oriented STEM activities developed in this study on students' images of engineers and engineering and their problem solving skills. In line with this purpose, solutions were sought to the following questions.

The following problem situations constitute the main point of this research.

- Is there a difference between the problem solving skills scale scores of the students studying with the current science curriculum and the students studying with engineering-oriented STEM activities?
- Is there a difference between the final "draw an engineer" test scores of the students who learnt with the current science curriculum and the students who learnt with engineering-oriented STEM activities?

What is STEM?

Individuals should have some skills in order to meet the needs of the period they live in and to solve the problems that may arise in the future. In our fast and highly variable age, individuals need to have skills called 21st century skills in order to solve these problems. These skills are of great importance for individuals to make better sense of the world they live in, to keep up with scientific and technological changes and developments rapidly, and to find solutions to the problems encountered at all these points.

In order to raise individuals with 21st century skills, various educational plans should be made and the skills of individuals should be developed within these plans. STEM education plays a role in educational policies for the development of 21st century skills. According to Beers (2012), 21st century skills and STEM education are very similar and support each other. STEM education overlaps with and contributes to 21st century skills at many points such as critical thinking, creativity, cooperation, communication and so on (Beers, 2012).

What is STEM Education?

STEM education is an approach that can provide high-level thinking against problems in nature (Yıldırım & Altun, 2014). In addition, according to Bybee (2010), raising individuals who can find solutions to complex problems, think systematically, comprehend technology and the nature of technology, and have developed creative and communication skills are among the main objectives of STEM education.

Considering the contributions of STEM education to students, according to the International Technology and Engineering Association (ITEA, 2009), these contributions can be listed as follows. • STEM education encourages students to understand the world and make discoveries. • It contributes positively to the students in terms of co-operation and playing an active role in group work and improves their self-efficacy. • By incorporating areas such as technology design and engineering into more school courses, it contributes to students being more interested in areas such as mathematics and science and keeps them motivated. • The technology literate plays an effective and positive role on students in terms of information and media literacy. • By enabling students to approach problems from different perspectives, it encourages them to question and think more.

Problem Solving Skills

Many complex situations encountered in daily life are seen as problems. Situations that cause discomfort in individuals and attempts to eliminate the difficulties in the problem are problem solving situations. Individuals should develop problem solving skills in order to eliminate problems (Taylan, 1990). Problem solving skill is defined as the solutions found by the individual at the point of application to the problems encountered (Üstün & Bozkurt, 2003). Individuals need to develop problem solving skills in order to cope with the problem situations they encounter in their daily lives more easily (Taylan, 1990).

Watts (1991) categorises problem solving skills into different categories. These skills are discovery skills that analyse and reveal the problem and define it, numerical skills that include situations related to making predictions and measuring, imagination skills that can see themselves in different positions and take on different roles, practical skills that include psychomotor skills, observation skills that include observing the qualities of assets and events,

Communication skills, which include the ability to perceive all kinds of verbal expressions, written materials, symbols, graphs and tables correctly and to express oneself correctly, examination and organisation skills, which include the ability to classify, divide and sort information, and finally social skills, which include cooperation with others.

Acquiring problem solving skills provides many advantages to individuals. Considering these advantages, individuals who can solve problems are open to innovations and can look at problems from different perspectives. Their innovation skills are developed and they exhibit a more innovative approach when solving problems. At the same time, individuals with developed problem solving skills exhibit a critical perspective towards problems and express their own decisions more clearly (Cited: Terzi, 2000). When we look at the other advantages provided by the development of problem solving skills; it is seen that it increases individuals' interest in learning, affects motivation positively and makes them more open to learning even in cases of failure (Tertemiz & Çakmak, 2004). For the development of problem solving skills, which provide many advantages and contribute to the development of many skills, it is important to exhibit a more professional educational approach in teaching these skills to students.

In the context of STEM education, engineering design process (EDS), which is seen as a pedagogical tool that provides interdisciplinary integration, can be used to provide students with problem solving skills (Basham & Marino, 2013; Çınar, 2019). Because the similarity between problem solving steps and the engineering design cycle used in STEM education is an important point for STEM education (Akçay, 2019).

Engineering Integration in Science Education

STEM education, which is seen as an interdisciplinary approach, provides the integration of different fields such as science, technology, engineering and mathematics (Bybee, 2010). Engineering, which is one of the STEM disciplines, has a great importance in science education today. According to the National Academy of Engineering (2010), engineering is defined as designs made within certain limitations. Within the scope of all these definitions, we can express engineering as any kind of design process that human beings attempt to find solutions to the problems they experience in line with their needs. Studies have shown that the integration of engineering into

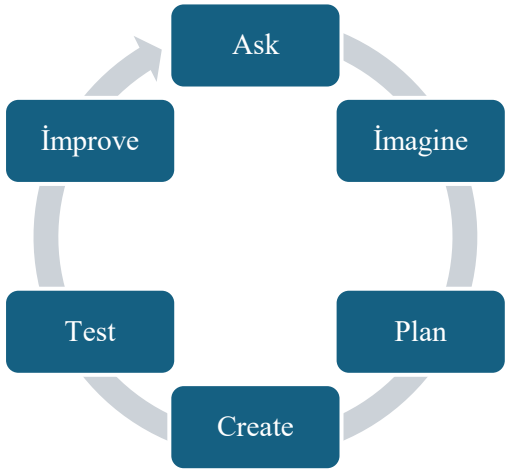
science and mathematics fields has a positive effect on students' academic achievement (Katehi et al., 2009).

Engineering Design Based STEM Education and Engineering Design Process

Children's curiosity about the natural world is important for science and science teaching. Engineering education plays an important role in order to increase this curiosity. Engineering education develops students in many areas such as designing, building various products, separating objects into parts and creativity, and at the same time supports science in making inquiries and understanding the natural world. The point where engineering, which progresses quite parallel to science, differs from it is that it is more flexible in solving problems and at the same time, it reaches solutions by putting engineering design processes to work (Cunningham, 2007). In engineering design processes, the approach required in the application of engineering design problems is referred to as "Design Based Science Education (TTFE)" (Wendell, 2008). In TTFE, engineering design process and scientific research are used together and support each other Apedoe et al. (2008).

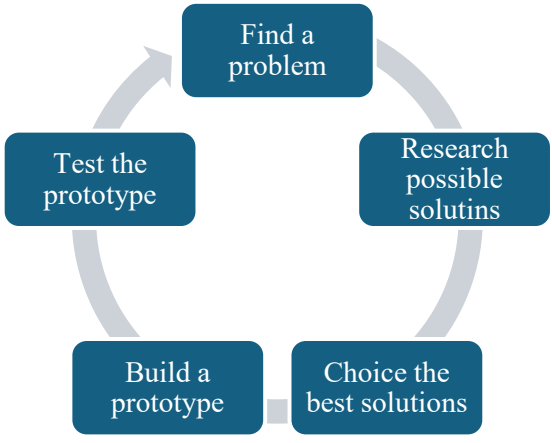
When the studies on TTFE are examined, it is seen that different researchers have designed these processes in different ways according to different age groups. For example, when we look at the engineering design processes specified by the National Aeronautics and Space Administration (NASA, 2011), the first step starts with asking a question about a specified problem. The desired points and limitations in the design are determined. In the next stage, imagining, the ideas put forward for the solution are evaluated and research is carried out in this context.

In the next planning stage, some of the solutions are selected and necessary drawings are made for them. In the creation stage, a prototype is created for the drawing. The product created for the solution of the problem is tested in the testing phase to see to what extent it solves the problem. If there is any problem with the created product at the point of solving the problem, it is corrected and revised in the development step, which is the last step of the cycle.



NASA Engineering Design Process Cycle (NASA, 2011)

Another application suitable for the level of primary school students is the study conducted by Wendell and Rogers (2013). Wendel and Rogers simplified the eight-step engineering design step prepared by the Massachusetts Department of Education and reduced it to five steps (figure 2.2., p.520).



Engineering Design Process (Wendell And Rogers, 2013)

Students' Perception of Engineers and Engineering

When perceptions are considered, all kinds of mental interpretations obtained from the outside world as a result of experiences can be considered. These interpretations play a very important role in all kinds of decisions of individuals and also give direction to individuals. Recently, with the inclusion of engineering in education programmes, what individuals know about engineering and their existing perceptions have started to be addressed. According to Cunningham (2004), individuals' perceptions of engineers and engineering professions are quite deficient.

When these perceptions are reduced to the generality of students, it is seen that there are many deficiencies in the subject. Some studies conducted so far have addressed students' perceptions of engineers and engineering. When we look at daily life, it is known that a large part of the students do not know exactly what engineering is and have wrong perceptions on the subject, although many assets seen in the environment are engineering products.

When the studies on students' perceptions of engineers and engineering are examined, the "Draw an Engineer Test" developed by Knight and Cunningham was applied to students of different age groups for 15 minutes. As a result of this study applied to different age groups, it was revealed that 30% of the students had perceptions mostly related to building-construction, 9% of the students perceived engineers as people who drive trains and the majority of the students perceived engineers as people who make repairs. Another result of the study was that a large proportion of the students perceived engineers as male in their drawings. In the last part of the study, the equipment in the drawings were analysed. As a result, it was observed that the students included repair tools such as hammers and emphasised themes such as cars, computers and houses under construction (Knight & Cunningham, 2004).

In many studies on students' perceptions of engineers and engineering, there are common results. Most of the time, engineers are seen as labourers working on construction by students. Students integrate engineering as a profession that only men can do. Thus, these misperceptions acquired at an early age show themselves in the future (Fralick et al., 2009; Lee et al., 2013; Şahin & Keser, 2016).

Capabianco et al. (2011) examined the engineering conceptions and perceptions of approximately 400 students studying from the 1st to the 5th

grades of primary school. It was determined that some of the students perceived engineers as people who repair engines and drive cars and vans, others perceived them as construction workers who build buildings and repair roads, and some of them perceived engineers as people who repair computers and electronic devices.

In another study conducted by Liu and Chiang (2019) with 390 secondary school students studying in a private school in Beijing, it was examined how students' perceptions of engineering changed according to grade level and gender. In this study conducted in a private school focusing on STEM education, "Draw an Engineer Test" was distributed to students as a drawing tool.

It was observed that both of the student groups, which participated in the study in approximately equal numbers, saw engineering as a profession that men can do and this ratio was approximately four times higher. When the change in engineering perception according to classes is analysed, it is seen that the perceptions of upper class students are different from those of lower class students. The reason for this is thought to be the increasing knowledge and life experience as they pass to the upper classes.

METHOD

Participants

The study group of the research consists of 6th grade students studying at Şehit Âdem Yavuz Secondary School in Şahinbey district of Gaziantep province in the 2021-2022 academic year. A total of 58 students studying in randomly selected 6J and 6K classes participated in the study. The classes of the experimental and control groups were decided by the researcher and the teacher teaching the course at the same time. Before the study, it was ensured that the classes were equal to each other. The experimental and control groups were determined by analysing the science exam scores of the students.

Research Model / Design

In this study conducted to determine the effect of STEM-based sound and properties activities on students' engineer and engineering images and problem solving skills, mixed research method was applied. According to Creswell and Clark (2007), mixed method is defined as collecting and

analysing quantitative and qualitative data and integrating the results at the end of the process. In this study, a quasi-experimental design with pretest-posttest control group was used to analyse quantitative research data. In this design, at least one variable is changed and the other variable is kept under control and the effects of the change are observed (Gay, Mills, & Airasian, 2009).

In the study, a quasi-experimental design with pre-test post-test control group was used for the analysis of qualitative data. Content analysis method was used to analyse qualitative data. In content analysis, similar data are collected and divided into codes. After the codes are grouped by the researcher according to similar content characteristics, themes are formed from the categories formed (Patton, 2002).

Table1: Research process

	QUALITATIVE RESEARCH	**QUALITATIVE RESEARCH**
DESIGN	Quasi-experimental design with pre-test-post-test control group	Quasi-experimental design with pre-test-post-test control group
DATA COLLECTION	Pretest (Problem Solving Skills Scale) Application Implementation of engineering orientated STEM activities (8 Weeks) Post Test (Problem Solving Skills Scale) Application	Pretest Draw an Engineer Test Implementation of engineering orientated STEM activities (8 Weeks) Final Test Draw an Engineer Test
ANALYSING THE DATA	Normality Test, Independent - Sample t test Dependent sample t test	Content Analysis

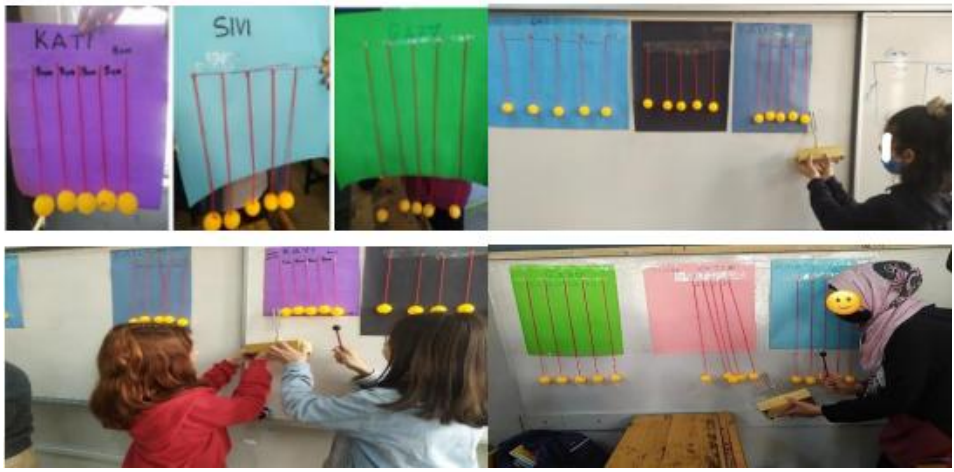
Application Steps

- The researcher developed 5 engineering-oriented STEM activities related to the Sound and Properties unit in accordance with the groups.
- In accordance with each STEM activity developed, worksheets containing the Engineering Design Process, in which students can comprehend how engineers work, were prepared and integrated into the relevant STEM activities.
- The experimental and control groups were given the necessary preliminary information about how the study would be conducted and how the process would proceed.
- "Problem Solving Skill Scale" and "Draw an Engineer Test" were applied to the experimental and control groups as pretests. After answering the 20-item problem solving skills scale, the students were given the "Draw an Engineer Test" and were asked to think of an engineer and draw by explaining what the engineer they thought of was doing in the working environment.
- After the pre-test, a presentation titled "STEM Engineering and Engineer Design Process" was made for 2 lesson hours in order for the experimental group students to better understand the engineering design process and to manage the process well during STEM activities and to have general information about engineers and engineering.
- The students in the experimental group were provided with instructional materials related to the Sound and Properties unit and worksheets containing the Engineering Design Process, and the students were made to fill in the worksheets during the activities by implementing STEM activities. Students were given two weeks for pre-test and post-test studies. Six weeks were allocated for the STEM Engineering and Engineering Design Process presentation and the implementation of STEM activities, and a total of 8 weeks were allocated for the entire process.
- While the students in the control group were taught in accordance with the current science curriculum, the experimental group students were divided into different groups every week and STEM activities were applied.
- "Problem Solving Skills Scale" and "Draw an Engineer Test" were applied to the experimental and control groups as post-tests.
-

Table2:Activities and Timeline

Week 1	7-11 March	Conducting pre-test
Week 2	14-18 March	Let's Create a Telephone Line Activity
Week 3	21-25 March	Moving Ping-Pong Balls Activity
Week 4	28 March-1 April	Vibrating Salt Grains Activity
Week 5	4-8 April	Let's Insulate Our Classroom Activity
Week 6-7	6-7. Week	I Design the Best Acoustic Structure Event
Week 8	2-7 May	Conducting the post-test

Visuals related to the Let's create a telephone line activity



Visuals related to the moving ping pong balls activity

Visuals related to the vibrating salt grains activity

Visuals related to the activity "Let's insulate our classroom

Visuals related to the activity "I design the best acoustic structure

Development of Materials

In this study, while teaching the lesson with the control group, the subject of sound and its properties in the science textbook of the curriculum was taught by taking into account the current science curriculum and the activities in the book were applied to the students. While teaching the lesson with the experimental group, five STEM activities developed with an engineering focus were applied to the students. STEM activities were developed by considering the current science curriculum. In the study, firstly, the acquisitions of the subject of sound and its properties in the curriculum were examined and five original engineering-oriented STEM activities were designed in line with the acquisitions and worksheets suitable for the activities were prepared.

The achievements of the science curriculum related to the Sound and Its Properties unit are given below.

Table3: Sound Propagation

F.6.5.1.1.	Predicts the environments in which sound can propagate and tests his/her predictions.
F.6.5.1.2.	Hearing Sound Differently in Different Environments
F.6.5.2.1	Discovers by experimenting that sounds are heard differently when the sound source changes.
F.6.5.2.2.	Discovers by experimenting that sounds are heard differently with the change of the environment in which the sound propagates. The concept of frequency is not introduced.
F.6.5.3.	Speed of Sound
F.6.5.3.1.	Compares the speed of sound in different environments. a.The speed of light and sound in air is compared through the events of lightning, thunder and lightning. b. It is emphasized that sound is a form of energy.
F.6.5.4.	Interaction of Sound with Matter
F.6.5.4.1.	Gives examples of reflection and absorption of sound.
F.6.5.4.2.	Makes predictions to prevent the spread of sound and tests their predictions
F.6.5.4.3	Explains the importance of sound insulation. Technological and architectural applications developed for sound insulation are mentioned.
F.6.5.4.4.	Gives examples of acoustic applications. Applications in modern and cultural architecture is emphasized. For example, reference is made to the acoustic architecture of the Süleymaniye Mosque.
F.6.5.4.5.	Designs an environment that will serve as an example of sound insulation or acoustic applications.

Data Collection Process and Tools

In the study, "Problem Solving Skill" scale was applied to examine the problem solving skills of the students and "Draw an Engineer Test" was applied to examine the engineer and engineering images.

In the study, the "Problem Solving Skill Scale" (PSS) was used to determine to what extent the problem solving skills of the control group students studying with the current programme (2018) and the experimental group students studying with engineering-oriented STEM activities changed before and after the application. Permission was obtained from the researcher for the scale. PSS was developed by Ge (2001) and translated into Turkish by Coşkun (2004). The scale includes 4 questions for the problem steps, 5 sub-sentences that can form an answer to each item, and 20 sentences in total. The sentences can be answered in the form of 5-point Likert type including "always", "often", "occasionally", "rarely" and "never" options. The scoring of the scale is "always" = 5, "frequently" = 4, "occasionally" = 3, "rarely" = 2 and "never" = 1 point.

As a result of the factor analysis conducted by Coşkun (2004), the scale was unidimensional and the variance was found to be 61.24%. The reliability coefficient of the 20 items in the scale was .76. In another study conducted by Çiftçi (2006) on 81 students, the reliability of the scale was found to be .72. In this study, the reliability of the scale including the pre and post-test items of the experimental group was calculated as .879; the reliability including the pre and post-test items of the control group was calculated as .763 and finally the reliability including the pre and post-test items of the experimental and control groups was calculated as .842

BMCT was developed by Knight and Cunningham (2004) and applied to 384 students belonging to different age groups. In this study, the drawing form prepared by Knight and Cunningham by taking into consideration the BMCT developed by Knight and Cunningham was used. Necessary permissions were obtained from the researchers for the related form. The students were given 1 class hour (40 minutes) for BMCT and were asked to draw an engineer working in his/her field and explain what exactly the engineer was doing.

Data Analyses

In the study, SPSS programme was used for the quantitative analysis of the problem solving skills scale data. It was examined whether the data obtained

from the scales related to the problem solving skills of the experimental and control groups showed normal distribution. For data analysis, Shapiro Wilk test is used when the number of data is 30 and below, and Kolmogorov-Smirnov test is used when the number of data is above 30 (Büyüköztürk, 2019). Since the number of data in the study was above 30, Kolmogorov-Smirnov values were examined, and it was seen that the results of the pre-tests and post-tests of the control and experimental groups, the pre-post-tests of the control group, and the pre-post-tests of the experimental group showed a normal distribution with a p value of 0.2 ($p>0.05$).

Levene's test was used in the homogeneity analysis to evaluate the equality of variance of the groups and the closeness of the groups to each other was evaluated. As a result, the p value of the total scores was examined to determine whether there was a statistically significant difference between the pretest scores of the experimental and control groups.

In line with the data obtained, parametric tests were used for all research problems. In the first research problem, Independent Samples T test was applied to determine whether there was a significant difference between the pretest scores of the experimental and control groups. In the second research problem, Independent Samples T test was applied to determine whether there was a statistically significant difference between the post-test scores of the experimental and control groups. In order to determine whether there is a statistically significant difference between the pre-test and post-test scores of the experimental and control groups separately, the Paired Simple T test, one of the parametric tests, was applied.

As a result of the research, qualitative data were used to analyse the questions in the Draw an Engineer Test (DIMT). The data were subjected to content analysis by the researcher, who is a science teacher, and a science teacher who is an expert in the field. In content analysis, data that are close to each other are coded and recurring codes are classified under determined themes (Miles, Huberman, 1994). When the drawings made by the students on BMCT were analysed, the drawings were divided into codes and themes. As a result, the frequency and percentage values of the codes and themes in the drawings are presented in the tables.

The content analysis conducted within the scope of the validity of the research was conducted by an expert science teacher other than the researcher. Another validity indicator of the research is that the steps applied during the research

were explained in detail and all drawings and interpretations were included. The qualitative data analysis of the research was conducted as stated above. The themes and codes determined for the reliability of this study were calculated by an expert science teacher using Miles and Huberman's (1994) reliability formula (reliability=agreement/agreement+disagreement). The agreement between the researchers was calculated as 90%. The reliability of quantitative data has been found in different previous studies. For example, as a result of the factor analysis conducted by Coşkun (2004), the scale was found to be unidimensional and the variance was found to be 61.24%. The reliability coefficient of 20 items in the scale was .76. In another study conducted by Çiftçi (2006) on 81 students, the reliability of the scale was found to be .72. In the study, the reliability of the scale including the pre and post-test items of the experimental group was calculated as .879, the reliability including the pre and post-test items of the control group was calculated as .763 and finally the reliability including the pre and post-test items of the experimental and control groups was calculated as .842.

RESULTS

In the problem-solving steps identified by Bingham based on Dewey's problem-solving approach, the first step is to recognize and feel the existence of a problem and to develop an interest in solving it. In the subsequent steps, the problem situation is clarified, followed by the processes of searching for and organizing the information necessary for a solution. Next, possible solutions are generated, the most appropriate one is selected, and finally, all processes are evaluated. According to Kuzgun (1992), one of the most important stages in this process is to clearly recognize the problem and accurately define the problem situation that disturbs the individual. Larkin (1980) emphasizes that problem-solving skills can be learned by students and that greater attention should be given to these skills in school practices. In the revised science curriculum (MoNE, 2018), within the scope of science, engineering, and entrepreneurship practices, students are expected to identify problems encountered in daily life, effectively solve these problems through alternative solutions, and develop skills for presenting the resulting products effectively. In addition, students are expected to develop various skills such as data presentation, recording observations, and interpreting graphs. In this respect, the development of students' problem-solving skills is of great importance.

In this study, the development of students' problem-solving skills and the extent to which these skills were affected were investigated. Based on the results obtained, differences between the problem-solving skills scale scores of students in the experimental group and those in the control group were examined.Within the scope of the study, five different STEM activities were applied to the students in the school environment as specified in the programme. After analysing different problem situations thoroughly in the activities given to the students, they were expected to find solutions to these problems effectively by following certain steps. Before and after these steps, the problem solving skills scale was applied to the students. In line with the findings obtained, the results were presented by comparing the pre- and post-tests of the groups within themselves and with each other.

In the first sub-problem of the study, it was examined whether there was a difference between the post-test Problem Solving Skills Scale (PSSS) scores of the students in the experimental group and those in the control group. For this purpose, the PSSS was administered to both groups after the intervention. According to the independent samples t-test, although the post-test PSSS scores of the students in the experimental group were higher than those of the control group, the difference between the group scores was not statistically significant. The results of the study indicated that the mean PSSS scores increased in both groups; however, this increase was greater in favor of the experimental group, while the control group showed a comparatively lower improvement.

When the results were analyzed, it was found that the experimental group achieved higher mean scores than the control group across all sub-dimensions. An examination of the post-test scores of both groups revealed an increase in scores in each group; the post-test mean score of the experimental group was higher than that of the control group. However, this difference between the groups was not statistically significant.

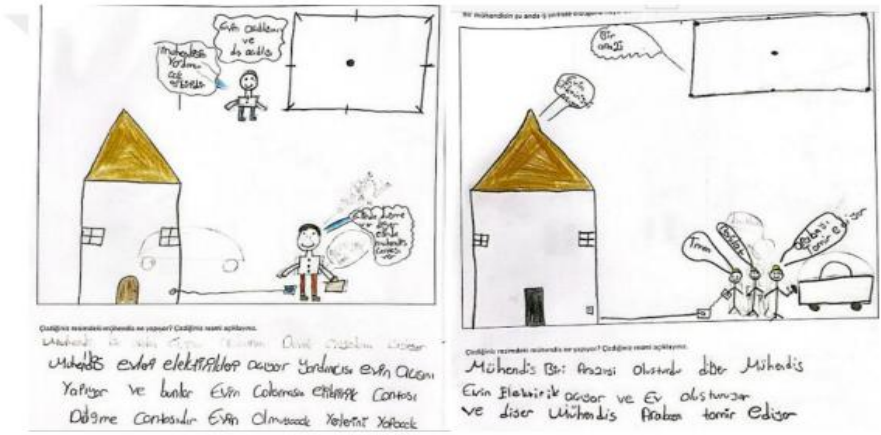
The higher post-test mean score observed in the experimental group suggests that the STEM activities were effective in improving students' problem-solving skills. To obtain more meaningful results regarding the research problem, it is recommended that a problem-solving skills scale that is more easily understood by students be developed to better examine the effects on problem-solving skills. One possible reason for the obtained results is that the study was conducted immediately after the COVID-19 pandemic, during

which students experienced difficulties in readjusting to school and demonstrated academic deficiencies.

In a study conducted with fifth-grade students, İnce et al. (2018) investigated the relationship between problem-solving skills and academic achievement by implementing various STEM activities. While the control group received instruction in accordance with the science curriculum, STEM activities were applied to the experimental group. The results of the study indicated that STEM activities enhanced students' problem-solving skills.

To determine changes in students' images of engineers and engineering within the context of STEM-based sound and properties activities, several comparisons were conducted: pre- and post-test comparisons between the experimental and control groups, pre- and post-test comparisons within the experimental group, and pre- and post-test comparisons within the control group.

The current study was analyzed under a total of eight themes: individuals involved in the drawing, construction structure, equipment included in the drawing, design/drawing, engineer, engineering, engineer's activities, safety, and number of engineers. Based on the findings, an examination of the control group's pre-test and post-test engineering perceptions revealed a decrease in the representation of all individuals depicted in the students' drawings. Within the construction structure theme, none of the students included different code groups such as laboratories, space stations, walls, or roofs in either the pre-test or the post-test.



Control group pre-test post-test drawings

Within the theme of equipment included in the drawings, it was observed that in both the pre-test and post-test, students frequently incorporated codes such as repair tools, tool bags, dishwashers/washing machines, and refrigerators. This indicates that students tended to perceive engineers primarily as repair workers, and their perceptions did not change in this regard.

When the design/drawing theme was analyzed, it was found that the codes related to planning/design (e.g., plans, projects, and prototypes) were more prevalent than other codes in the pre-test; however, the percentages of these codes decreased in the post-test.

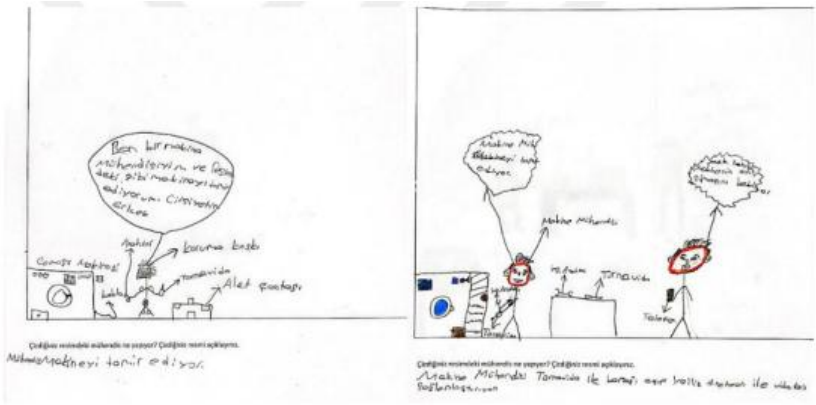
An analysis of the engineer theme revealed that representations of male engineers in both the pre-test and post-test were considerably higher than those of female engineers, although the proportion of female engineers depicted in the drawings showed a slight increase in the post-test. Overall, the drawings indicated that students predominantly perceived engineers as male professionals working in the field, devoted less attention to the planning and design stages, and represented female engineers much less frequently in both fieldwork and planning contexts.

Control group pre-test post-test drawings

When the engineering theme in the test was examined, it was found that the majority of students predominantly emphasized civil engineering in their drawings. Although this proportion decreased slightly in the post-test, mechanical engineering emerged as a replacement for this decline. Overall, the findings indicate that students tended to perceive engineering mainly as

civil engineering, included very few other engineering disciplines, and that their perceptions did not change substantially in the post-test.

When the theme of engineers' activities was analyzed, it was observed that students most frequently included codes related to prototyping, design, and supervision/management in their drawings. However, the prevalence of these codes decreased in the post-test, while codes related to repair and construction increased, indicating a shift in students' perceptions toward viewing engineers primarily as individuals who repair and build. This tendency may be influenced by the students' living in Gaziantep, an industrial city. An analysis of the safety theme revealed that students commonly emphasized helmets and hard hats in their drawings.



Control group pre-test post-test drawings

In the final theme, namely the number of engineers, it was determined that students predominantly perceived the engineer as a single individual working alone. Based on all these findings, it was concluded that there was no change in the perceptions of engineers and engineering among students in the control group. Another noteworthy finding of the study is that, despite the time interval between the pre-test and post-test, there were minimal differences between most students' pre-test and post-test drawings, and the codes they emphasized were largely represented in similar ways.

In the present study, an examination of the pre-test and post-test differences in the experimental group revealed that students' perceptions changed to a considerable extent. When the theme of individuals represented in the drawings was analyzed, it was found that the proportion of engineers depicted did not change, whereas there was a decrease in codes such as worker and

machine operator. Additionally, one student who included the code "astronaut" in the pre-test replaced it with "agricultural engineer" in the post-test.

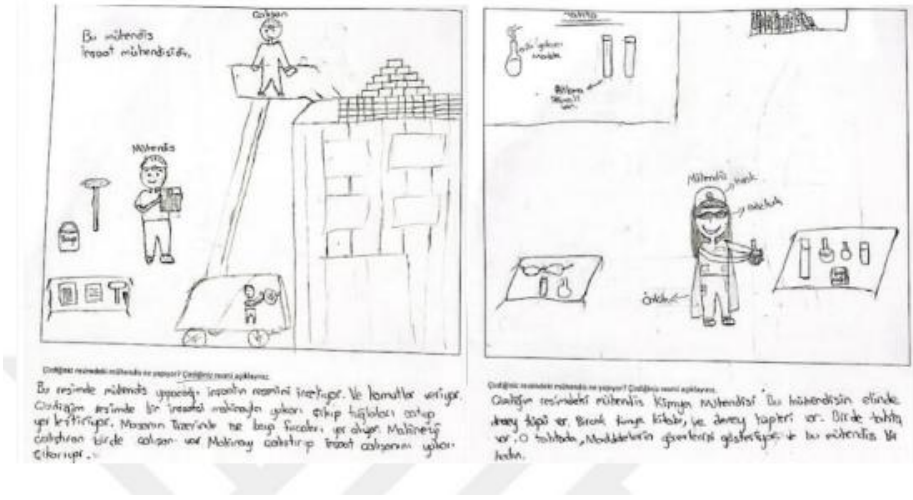
An analysis of the construction structure theme showed a decrease in the use of the "building" code, which was replaced by diverse work environments such as workshops, laboratories, warehouses, environmental areas, and space stations. These findings indicate that students' perceptions shifted in the post-test toward understanding that the working environment of engineers, particularly civil engineers, is not limited solely to buildings.

When the post-test data related to the equipment depicted in the drawings were examined, students were found to emphasize concepts such as aircraft, drones, rockets, and satellites. They also included new codes such as energy systems, biomedical devices, and laboratory equipment, rather than focusing solely on repair tools. Overall, the drawings reflected a broader range of engineering fields and demonstrated a clear change in students' perceptions compared to the pre-test.

Experimental group pre-test post-test drawings

When the design/drawing theme was analyzed, a decrease was observed in the code groups related to drawing. This decrease is thought to result from a shift in students' perceptions of engineers—from professionals who primarily work at construction sites designing and producing projects to those who work in diverse settings such as the field, laboratories, environmental contexts, and agricultural areas. An analysis of the engineer theme indicated that students' perceptions changed to a considerable extent. While male engineers were

predominantly represented in the pre-test drawings, their representation decreased in the post-test, whereas the number of female engineers depicted increased in the post-test. When the engineering theme was examined, civil engineering, which was heavily emphasized in the pre-test drawings, appeared at a much lower rate in the post-test. Instead, students included a wider range of engineering disciplines in their post-test drawings, such as environmental engineering, chemical engineering, biomedical engineering, agricultural engineering, aerospace, engineering and food engineering.



Experimental group pre-test post-test drawings

When the theme of the activities performed by the engineer is examined, it is seen that different code groups such as building, prototype designing, supervising and directing codes are less common, while different code groups such as production, software production, control testing, experimentation, research are more common in student drawings. In the post-test drawings of the students, the perception that they see an engineer as a person working only in the field of construction has been replaced by the perception of engineers who do research, experiment, produce, control and test in different fields of work. When the safety theme is examined, it is seen that there is a significant decrease in the helmet, hard hat code, and codes such as work goggles, masks and glasses are more frequently mentioned in the drawings. It is thought that the change here is due to the students' drawings of engineers working in different working areas instead of the construction site in the post-test drawings. Considering the number of engineers, it is seen that the students emphasised teamwork more in the post-test than in the pre-test.

Experimental group pre-test post-test drawings

When the groups were compared, it was observed that the control group's drawings showed no change between the pre-test and post-test; students' images of engineers and engineering remained the same, and the drawings were highly similar when the related visuals were examined. In contrast, the experimental group's drawings changed significantly, with an increase in both the variety and number of code groups, indicating a substantial change in students' perceptions.

It can be stated that the similarities between the experimental and control groups were primarily evident in the pre-tests. As the students lived in Gaziantep, an industrial city, and were involved in working life at an early age, they possessed relatively detailed knowledge of repair tools. Therefore, the existing schemas of engineers and engineering among students appear to be more closely associated with the construction sector and repair work.

When previous studies related to the topic are examined, similar findings can be observed. For instance, in a study conducted by Gülhan and Şahin (2016) with fifth-grade students, the effects of STEM activities on students' perceptions of engineers and engineering were investigated. Responses to the question "Who is an engineer?" indicated that perceptions of civil engineering were dominant in the pre-test. However, following the STEM activities, most students demonstrated differentiated and more positive perceptions in the post-test. The results showed that 71.5% of the experimental group students exhibited improvement, while 28.5% did not show improvement.

Ünlü and Dökme (2016) conducted a study with 72 gifted students to examine their perceptions of engineering. The findings revealed that students predominantly associated engineering with civil engineering and mainly referred to male engineers. One notable result was that students included a stronger design dimension in their drawings. This outcome was attributed to the students' special abilities and their exposure to robotics and experimental activities in their lessons. In the present study, based on student drawings, it was observed that instead of depicting civil engineers constructing bridges, roads, dams, or tunnels, students primarily drew engineers who build houses. Following civil engineering, computer engineering was the next most frequently represented field, with computer engineers typically depicted as individuals who repair broken computers.

In another study by Knight and Cunningham (2004), which aimed to introduce children to the concepts of engineers and engineering at an early age, results similar to those of other studies were obtained. To determine students' perceptions, participants were asked the question "What does an engineer do?" and were requested to draw an engineer in a working environment. Analysis of drawings from students in grades 3 through 12 showed that 30% associated engineers with construction and repair work. While 9% of students perceived engineers as train drivers, 39% of the depicted engineers were female and 61% were male. Students frequently emphasized repair tools and portrayed engineers repairing cars and constructing houses and bridges.

In a case study conducted by Liu and Chiang (2020) with secondary school students in Beijing, students' perceptions of engineering were examined across grade levels and gender. The study analyzed data from 390 middle school students and found that students commonly associated engineers with buildings and predominantly depicted male engineers. Unlike the findings of many previous studies, it was revealed that the accuracy of students' perceptions improved as grade level increased. The researchers suggested that misconceptions about engineering may stem from family influences, school experiences, teachers, textbooks, comic books, media, and television.

A review of other studies on this topic indicates that both teachers and students often perceive engineers as individuals who primarily engage in repair work (Fralick et al., 2009; Karataş et al., 2011; Yıldırım, 2018). Such misconceptions may hinder effective understanding of the "Science, Engineering, and Entrepreneurship" components of the science curriculum. Considering all these findings, the literature highlights the need to address and

correct teachers' and students' misconceptions regarding engineers and engineering.

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Climate Change Education, Digital Technologies, and Artificial Intelligence Title

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INTRODUCTION

Climate change is no longer just an ecological crisis; it is a multifaceted and highly complex phenomenon that is shaking entire global systems. Beyond threatening natural habitats, this crisis profoundly disrupts economic balances, social fabric, and international political stability. Data shared by the Intergovernmental Panel on Climate Change (IPCC, 2021). Unequivocally proves that global temperature increases are directly related to human activities (IPCC, 2021; 2023).

These reports warn the international community about the collapse of ecosystems, chronic threats to human health, and serious risks to sustainable development goals (IPCC, 2021). In this context, it is clear that combating the climate crisis cannot be won solely through technical improvements or short-term political maneuvers. Solving the problem necessitates a fundamental, education-based approach that will transform individuals' knowledge levels, attitudes, and ultimately, actions.

Education is considered a transformative lever in mitigating the devastating effects of climate change and preparing societies for this new reality. The United Nations Educational, Scientific, and Cultural Organization (IPCC, 2021). argues that modern education should not be limited to the transfer of theoretical knowledge. Instead, it aims to develop individuals' scientific literacy as well as their critical thinking, systems-based analysis, and responsible global citizenship skills (UNESCO, 2017; 2020). This visionary approach is fully aligned with the Sustainable Development in Education (SDE) strategic framework. SDE principles define climate change not as an isolated environmental problem, but as an integral and central part of global sustainability goals. In this way, education is positioned as both a prevention and adaptation strategy in the fight against the climate crisis.

However, climate change education, by its very nature, involves a high degree of complexity and interdisciplinary depth. The variable nature of climate systems, the difficulties in predicting long-term impacts, and understanding the dynamics of human-nature interaction challenge the limits of traditional classroom teaching methods. This complex structure makes the use of innovative pedagogical and technological tools essential in all educational processes, especially science education.

Digital technologies hold enormous potential in overcoming the conceptual and cognitive barriers encountered in climate change education. Technology-supported teaching methods play a crucial role in making abstract concepts concrete and observable, as well as in understanding environmental changes over long periods. In particular, the processing and visualization of complex datasets help students gain a deeper understanding of the subject.

In this context, simulations, digital datasets, interactive mapping systems, and enriched online learning environments facilitate a micro-level understanding of macro-level issues such as climate change (OECD, 2019). These tools allow students to experience the consequences of different environmental interventions in a risk-free environment by creating "what-if" scenarios.

The function of digital tools in climate education is not limited to passive content delivery. These technologies enable learners to interact directly with real-world data, work with complex climate models, and assess the potential implications of various environmental policies. The OECD (2019) states that digital instruments, particularly in the context of science education, support students' higher-order thinking skills and scientific reasoning abilities.

In recent years, artificial intelligence (AI) applications, the most advanced stage of digital transformation, have become a central topic of discussion in the education sciences literature. AI has the capacity to optimize educational processes according to individual needs through the use of learning analytics, personalized learning paths, and dynamic feedback systems (Holmes et al., 2019). This technological leap marks a new era in the dissemination of climate literacy. However, the integration of AI with climate education not only offers pedagogical opportunities but also raises serious ethical debates. UNESCO (2021) emphasizes that the use of AI in education should be carried out in accordance with the principles of data privacy, algorithmic transparency, accountability, and equal opportunity, thereby preventing the deepening of the digital divide. Technological integration, lacking an ethical framework, can harm the democratic nature of education.

Furthermore, the paradox between technology and sustainability should not be overlooked. The energy consumption and carbon footprint of digital infrastructures and high-processing-power artificial intelligence systems require critical evaluation from the perspective of the philosophy of combating climate change itself. Educators are expected to incorporate the environmental costs of these tools into the teaching process while simultaneously using these technologies. Consequently, climate education, digitalization, and artificial intelligence are generally examined as independent fields in the current literature. This study aims to provide a theoretical roadmap for educators and policymakers by combining these three disciplines from a holistic sustainability perspective. This section, which presents a conceptual analysis rather than application-based examples, serves as a scholarly reference for researchers working in the fields of science education and educational policy.

Climate Change and the Role of Education

Climate change is currently considered a multifaceted global crisis with interconnected scientific, social, and political dimensions. Recent data from the Intergovernmental Panel on Climate Change (IPCC) confirms that human activity is the primary driver of global temperature increase, posing irreversible risks to ecosystem sustainability, public health, and economic structures (IPCC, 2021; IPCC, 2023). This scientific reality demonstrates that combating the climate crisis cannot be won solely through technical and industrial innovations; instead, education-focused interventions that transform individuals' knowledge levels, attitudes, and modes of action are essential.

In this process, education goes beyond a simple effort to raise awareness, aiming to strengthen individuals' capacity to analyze complex ecological problems and make rational, ethical, and responsible decisions in the face of these crises. This strategic role of education enables learners to grasp the dynamics of environmental problems while simultaneously equipping them with the problem-solving skills necessary to build a sustainable future.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) argues that quality climate change education should synthesize scientifically based knowledge transfer with critical thinking and values education (UNESCO, 2015). Within this holistic approach, climate change education is considered a "transformative learning process" that reshapes an individual's worldview and social practices, and is positioned as a key mechanism in achieving global sustainability goals.

Sustainable Development (SD) and Climate Change in Education

Sustainable Development in Education (SDE) is a comprehensive pedagogical model that prepares individuals for the uncertainties of the future, aiming to equip them not only with theoretical knowledge but also with ethical values and practical skills. As emphasized by UNESCO (2017), this approach adopts a holistic perspective, addressing environmental, social, and economic dynamics in an integrated manner, without separating them. The goal is to strengthen learners' ability to analyze complex systems and make strategic decisions that will shape the future. Within this broad perspective, the issue of climate change constitutes one of the fundamental building blocks and the primary focus of the ESD discipline. The process of combating the climate crisis has transcended being merely a technical subject of the natural sciences and has become central to the philosophy of sustainable development. In this context, climate change education is considered one of the most strategic and transformative components in achieving the ideal of building a sustainable world.

As expressed by Rieckmann (2018), the ESD paradigm evaluates climate change not only as a scientific phenomenon but also in terms of

ethical values, social justice, and intergenerational responsibility. This in-depth understanding elevates climate-focused education processes beyond mere technical knowledge transfer, making them a key mechanism for achieving global sustainable development goals and driving societal transformation.

Climate Literacy

Climate literacy, in its broadest sense, is defined as the ability of individuals to understand how climate mechanisms function, to accurately analyze the fundamental triggers of changes in this system and their global implications, and to translate this acquired scientific knowledge into informed decisions (USGCRP, 2009). This conceptual framework is not limited to a purely intellectual knowledge acquisition process; it offers a multifaceted content encompassing an individual's attitudes towards the environment, ethical values, and behavioral patterns in daily life.

Current research in the literature clearly demonstrates that science education holds a strategic and central position in increasing societal awareness and literacy regarding climate issues (McBride et al., 2013). From a scientific perspective, science education provides a conceptual foundation for students to understand natural phenomena and human-nature interaction, enabling the construction of climate awareness within an academic discipline. Nevertheless, the abstract concepts inherent in the phenomenon of climate change, the long duration of the process, and the scientific uncertainties it contains make it difficult for learners to concretize this complex issue in their minds and develop a holistic understanding. These pedagogical challenges necessitate moving beyond traditional teaching methodologies and integrating technology-supported, innovative educational approaches that will strengthen climate literacy within the system.

Climate Change Education in Science Education

Science education plays a central role in deciphering and grounding the complex mechanisms underlying global climate change on a scientific basis. Critical themes such as atmospheric dynamics, global energy balances, and the direct impacts of human activities on ecosystems form the core curriculum components of science education. However, the multifaceted and interdisciplinary nature of the climate crisis renders a teaching model limited to traditional and subject-based approaches insufficient (Stevenson et al., 2016). This necessitates a shift to a more inclusive educational model that expands the boundaries of science education. In response to this pedagogical need, the Socio-Scientific Issues (SSI) approach provides a robust framework for climate change education, blending scientific knowledge with social and ethical values. This methodology aims not only to teach students scientific facts but also to strengthen their ability to critically analyze and

make ethically based decisions in the face of complex environmental crises (Sadler, 2011). By placing science within a social context, SSI enables students to view the problems they encounter not merely as technical data, but as real-life issues that have significant implications.

Restructuring science education from this holistic perspective is essential for building a learning environment that serves the ideal of sustainability. This process, where scientific data is integrated with social responsibility, lays the groundwork for individuals to become more conscious, active, and solution-oriented citizens in the face of global problems. Therefore, creating interdisciplinary synergy by stretching the boundaries of science in climate change education is considered a key strategy in achieving sustainable development goals at the pedagogical level.

Digital Technologies in Climate Change Education

Digital technologies offer significant pedagogical advantages in incorporating multifaceted and complex issues, such as climate change, into the educational process. Simulations, interactive data repositories, and digital visualization techniques play a facilitating role in the teaching process, enabling a more rational understanding of dynamic climate structures and atmospheric changes (Jacobson vd., 2016). Furthermore, the OECD (2019) emphasizes that such technological tools significantly support students' higher-order cognitive capacities and thinking skills in the context of teaching complex systems.

Digital platforms enhance the educational process by enabling students to interact directly with concrete and real-time climate data. Thanks to these technological capabilities, individuals can reason about various environmental scenarios and gain a deeper understanding of climate change education, moving beyond superficial information transfer. These tools prepare the ground for the internalization of theoretical knowledge within a practical and inquiry-based framework, thereby developing learners' analytical skills.

However, the mere existence of digital tools is not sufficient for academic success; these instruments must have a high-quality framework to create real pedagogical value. The extent to which digital resources can be used effectively for educational purposes is directly related to the quality of instructional design and how competently these tools are integrated with curriculum objectives (Means et al., 2014). Therefore, the potential of technology in climate education can only be fully realized through strategic and pedagogical planning.

Artificial Intelligence in Climate Change Education

Artificial intelligence (AI) applications, which have gained momentum in the field of educational technologies in recent years, are attracting great academic interest thanks to their ability to customize learning processes according to each individual's unique pace and style. While Holmes et al. (2019) state that these systems deepen the educational experience through personalized content production, it is also predicted that AI can play a key role in developing flexible and intelligent learning environments that will strengthen individuals' climate literacy in the field of climate change education.

In addition to technological possibilities, the ethical and social dimensions of this transformation must also be considered. UNESCO (2021) emphasizes that the use of artificial intelligence in education must be structured within the framework of transparency, fairness, and ethical standards, drawing attention to the potential risks in this area. This approach reminds us that protecting social justice and data security during the integration of technology into pedagogical processes is at least as important as technical efficiency.

Finally, the ecological cost of artificial intelligence systems constitutes a critical point in the context of climate change education. The high energy requirements and environmental impacts associated with the operational processes of these advanced systems must be carefully analyzed in a manner that aligns with the goals of combating the climate crisis. Therefore, when evaluating the role of artificial intelligence in education, both its cognitive contributions and its environmental consequences, such as its carbon footprint, should be considered from a holistic perspective.

Ethics, Equality, and Sustainability Dimensions

The inclusion of digital technologies and artificial intelligence systems in climate change education processes raises several profound ethical debates, including digital inequality and access issues. This phenomenon, referred to as the "digital divide," can hinder disadvantaged groups with limited access to technological resources and digital infrastructure from receiving or fully benefiting from climate change education (OECD, 2021). These access barriers constitute not only an educational problem but also a structural problem directly related to the principles of sustainability and social justice.

Regarding the ethical foundation of technological development, Floridi et al. (2018) argue that AI-based applications should be designed with a human-centered approach and in accordance with universal ethical principles. This approach is entirely consistent with the goals of raising awareness and fostering responsibility, which are fundamental aims of climate change education. Designing AI algorithms in a transparent,

accountable, and unbiased manner increases the reliability of educational processes and ensures they serve sustainability goals.

In conclusion, the role of digital tools in climate education necessitates maintaining a delicate balance between technological progress and social equity. Removing barriers to accessing technology is crucial to ensuring that educational efforts aimed at addressing the climate crisis do not conflict with sustainability ideals. Ensuring that ethical principles guide technological transformation, protecting equal opportunities in education, and making the transformative power of education accessible to all individuals in building a sustainable future are fundamental requirements of this process.

RESULTS and SUGGESTIONS

The devastating effects of the climate crisis on ecological, economic, and social systems necessitate a transformative approach that transcends traditional educational paradigms. Theoretical analysis has shown that climate change education is not merely about transferring knowledge, but a "transformative learning process" that reconstructs individuals' worldviews. In this process, the Sustainable Development in Education (SDE) framework offers strategic guidance by addressing the climate issue from an ethical and social justice perspective.

Digital technologies and artificial intelligence serve as critical pedagogical tools in concretizing the abstract concepts and long-term changes inherent in climate science. Simulations and personalized learning pathways, in particular, enable students to analyze complex climate models by developing higher-order thinking skills. However, the full potential of this technology is directly related to the quality of instructional design, algorithmic transparency, and bridging the gap between access and learning, often referred to as the "digital divide."

In addition, the high energy consumption and carbon footprint resulting from the use of technological tools create a "technology-sustainability paradox" that contradicts the principles of climate education. Consequently, digital transformation in education should be structured not merely as a pursuit of technical efficiency, but within a human-centered ethical framework that also considers social equity and environmental costs.

To enhance the effectiveness of digital tools and artificial intelligence in climate change education, educational policies need to be revised with an interdisciplinary approach. In this context, digital literacy, climate literacy, and ethical use of artificial intelligence should be prioritized in teacher training. Curriculum design should strengthen students' critical awareness by making the environmental costs created by technological tools themselves a subject of discussion.

In line with the principle of social justice, international collaborations and funding mechanisms should be developed to ensure access to climate education for disadvantaged regions and groups with weak technological infrastructure. Furthermore, standards should be established for the transparent and unbiased design of artificial intelligence algorithms, and the alignment of these processes with sustainability goals should be regularly monitored.

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High School Students' Approaches to Learning and Learning Styles in Terms of School Type

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ABSTRACT

The aim of this study is to examine the relationship between high school students' approaches to learning and their learning styles, and to determine whether these variables differ according to school type. The study was designed as non-experimental quantitative research using a cross-sectional survey model. The study group consisted of 11th grade students attending science high schools, Anatolian high schools, social sciences high schools, imam hatip high schools and vocational high schools in Erzurum, Türkiye. Using convenience and stratified sampling, data were collected from 427 students; 39 forms were excluded as invalid and analyses were conducted on 388 students. Data were gathered through the Grasha–Reichmann Student Learning Styles Scale, the Study Process Questionnaire (Approaches to Learning Inventory) and a demographic information form prepared by the researcher. Descriptive statistics, Pearson correlation analysis, MANOVA and Chi-square tests were used for data analysis. The findings revealed that students predominantly adopted a surface approach to learning across all school types, and that there were no significant differences in deep and surface approaches according to school type. However, significant differences were found between school types in terms of independent and dependent learning styles; independent style was more prevalent among students in social sciences and science high schools, whereas dependent style was more common among Anatolian high school students. Moreover, the deep approach to learning was positively associated with independent, collaborative, participant and competitive learning styles, and negatively associated with the avoidant style. The surface approach was positively related only to the avoidant style. These results suggest that the exam-oriented structure of the education system strengthens students' tendency towards surface learning, and that secondary education curricula should be redesigned to foster deep learning and to better align instructional processes with students' dominant learning styles.

Keywords: approaches to learning, learning styles, high school students, school type, quantitative research

INTRODUCTION

It is accepted that education is a fundamental human right. Every individual has the right to education and schools must be open to all individuals on the basis of equality in order to ensure equal opportunities (Derin Kılıç, 2025). In educational research, the learning process is described as a complex phenomenon with a multidimensional structure that cannot be easily defined (Alkhateeb & Bani-Milhem, 2020). In the literature, there are studies that attempt to explain this complex process through dimensions such as

environment, curriculum, instructional materials, teaching methods and techniques, approaches to learning and learning styles. As we know, in today's VUCA (Volatility, Uncertainty, Complexity and Ambiguity) world, where change is greater than ever before, curriculum is considered to have a direct impact on training the qualified workforce that societies need. In this regard, many countries are making significant efforts in the field of education, particularly in curriculum development (Derin Kılıç & Küçükoğlu, 2024). Within this body of work examining the learning process, it is observed that studies focusing on learners' approaches to learning have gained particular prominence (Marougkas et al., 2023). As greater importance is attached to individuals' lifelong learning and development in a globalizing world, interest is shifting from research that merely investigates learning outcomes to studies that explore how individuals learn. Accordingly, in literature reviews, research focusing on the learning process rather than on the results or products of learning has come to the forefront (Duff et al., 2004; Hong et al., 2023). One of the key elements that has a direct influence on the learning process is approaches to learning (Erdal, 2024). Although approaches to learning appear as a theoretical construct, they in fact reflect the learner's internal motivation and orientation when attempting to learn a topic, namely whether the learner focuses on understanding or on memorization (Alkhateeb & Bani-Milhem, 2020; Çağdaş, 2023; Entwistle, 1991). In research on the learning process, Ference Marton was the first scholar to conceptualize approaches to learning (Ozan et al., 2017). According to Marton and Säljö (1976), if the products emerging at the end of the learning process differ from one another, then the learning process itself must also vary from person to person. Individuals prefer different approaches in order to analyse information and integrate what they have learned into their existing knowledge structures (Teoh & Yap, 2015). Academic studies on approaches to learning provide foundational knowledge that can significantly inform curriculum development efforts and national education policy in terms of supporting learners' development (Hong et al., 2023). During the development of education policies and curricula, data to be gathered from learners such as their approaches to learning and learning styles can make important contributions to the curriculum development process. Approaches to learning are crucial if students are to manage the learning process effectively and achieve the intended outcomes (Aktunç, 2023).

Approaches to Learning

Marton and Säljö (1976) conceptualized approaches to learning in two dimensions: deep and surface (Ozan et al., 2017). Although students may choose different approaches depending on the content to be learned, approaches to learning vary considerably according to the teaching–learning environment (Çağdaş, 2023). In his study, Ekinci (2009) reported that students' approaches to learning differ according to their intentions and that these can be divided into an intention to understand (deep approach) and an intention merely to pass the course (surface approach). Teoh and Yap (2015) argue that a surface approach to learning is characterized by rote memorization and arises from a desire to succeed with minimum effort, whereas a deep approach to learning, in contrast, involves a more detailed and meaningful engagement with the material. Reviews of the literature suggest that the surface approach represents a more short-term, transient form of learning, while deep and strategic approaches are associated with more long-term learning (Aktunç, 2023; Alkhateeb & Bani-Milhem, 2020; Arslan, 2017; Teoh & Yap, 2015). It has also been demonstrated in research that students who adopt a deep approach to learning produce higher-quality learning outcomes at the end of the learning process (Trigwell et al., 1999).

Learning Styles

Another dimension of the learning process is learning styles, which refer to learners' differences in how they approach learning. For the educational process to be carried out effectively, individual differences such as learning styles need to be taken into account (Jilardidamavandi et al., 2011). The concept of learning styles was first introduced in 1960 by Rita and Kenneth Dunn and is treated as a set of biological and developmental behaviours that make the learning process more effective (Ataseven, 2014). The concept emerged as a result of research on individuals' differences in learning (Güven, 2004). According to Demir and Gürbüz (2020), learning styles express individuals' personal preferences and tendencies in the processes of acquiring, processing and recalling information. Each individual uses different methods and strategies in the learning process; these differences are referred to as learning styles. Learning styles are also defined as learners' preferences and priorities in the learning process (Zhou et al., 2024). Learning styles are important for enabling individuals to participate more effectively in educational processes and for adapting teaching methods to individual needs. In light of the literature reviewed, it would not be inaccurate to define learning styles as the individual abilities and preferences that learners draw upon during the learning process (Alan, 2017; Ataseven, 2014; Yadav & Shukla, 2021; Zhou et al., 2024). Recognizing learners' learning styles in the educational process, and teachers' awareness of these styles, as well as organizing the learning environment and shaping the teaching process accordingly, increase the efficiency of learning (Farid & Abbasi, 2014; Türker & Bostancı, 2023).

Considering that approaches to learning and learning styles vary according to different individual characteristics, differentiation strategies gain importance in instructional design. Differentiated teaching practices based on approaches to learning and learning styles offer students opportunities to access information more effectively and to make learning more permanent (Veznedaroğlu & Özgür, 2005). For example, the use of visual materials for students with a visual learning style, or the provision of hands-on experiences for individuals whose concrete experience style is dominant, are among the suggested strategies for creating effective learning environments. The convergence of students' learning styles with teachers' teaching styles on common ground makes the learning process more effective (Altun & Yazıcı, 2010).

As a result of various definitions and studies by different researchers, several learning style models have been proposed over the years, including those of Dunn and Dunn (1978), Kolb (1984), Gregorc (1985), Felder and Silverman (1988), and Grasha and Reichmann (1996) (Ataseven, 2014; Cimermanova, 2018; Çağdaş, 2023; Kuzu, 2009; Türker & Bostancı, 2023). Identifying learning styles helps educators adapt their teaching methods to individual differences. In this way, students' learning processes become more efficient and their academic achievement increases. For instance, one study found that instruction structured according to preservice teachers' dominant learning styles had a positive effect on their academic achievement (Ergen & Gürbüz, 2019).

According to Grasha and Reichmann, learning styles are related to the extent to which individuals interact with their environment, their peers and the learning context during the learning process (Zencir, 2024). Grasha and Reichmann classified learning styles into three dimensions and six styles: participant–avoidant, collaborative–competitive and dependent–independent (Güven, 2004). Explanations of the categories in Grasha and Reichmann's classification of learning styles, as reported by various researchers, are presented in Figure 1 (Dağ & Karamustafaoğlu, 2023; Gayef et al., 2023; Güven, 2004; Zencir, 2024).

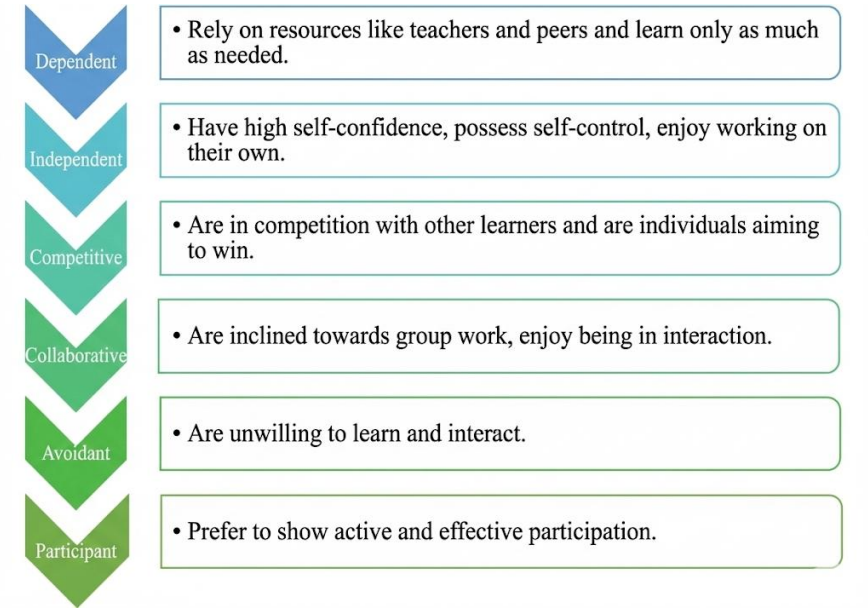

Figure 1: Grasha-Reichmann's Learning Styles

According to Sarıtaş and Süral (2010), the Grasha–Reichmann learning styles model is also directly related to students' approaches to learning. This relationship is one of the reasons why the Grasha–Reichmann Student Learning Styles Scale was chosen for the present study.

Learning Environment

Another key component of the learning process, and a concept that is related to both learning styles and approaches to learning, is the learning environment, that is, the school itself. In their study, Trigwell et al. (1999) demonstrated that students' approaches to learning are associated with their environment. In his research, Arslan (2017) also examined approaches to learning in terms of school type and reported significant differences. The present study aims to examine and reveal the differences in approaches to learning and learning styles according to school type, to contribute to the literature, and to offer recommendations to curriculum decision-makers and authorities.

In light of the literature review conducted, some studies on learning styles and approaches to learning are presented in Table 1.

Table 1: Related Researches

Author(s)	Study Group	Method	Variables	Findings
Ma (2024)	Instructional materials	Qualitative	Learning styles and Christian education	It was concluded that learning styles should be adopted and implemented in Christian education.
Nar (2024)	5th, 6th and 7th grade lower secondary school students	Quantitative	Academic achievement, attitude towards the course, gender, grade level, sociocultural environment and approaches to learning	Significant differences were found in students' academic achievement scores by grade level, parents' educational status and environment; in attitude scores by grade level; and in approach-to-learning scores by gender, grade level and environment. A positive correlation was identified between attitude mean scores, deep approach to learning and academic achievement.
Hong, Liu and Zhao (2023)	Preschool children	Quantitative	Preschool children's approaches to learning, gender, social skills, family income, family education level, school type and only-child status	It was concluded that all variables except being an only child produced significant differences in children's approaches to learning.
Erdal (2024)	Vocational school students	Quantitative	Relationship between approaches to learning and academic achievement	A negative relationship was found between the surface approach to learning and achievement, while no relationship was found between the deep approach to learning and achievement.
Zencir (2024)	9th grade students	Quantitative	9th grade students' learning styles, academic achievement in English and motivation	The independent learning style was found to be the highest and the competitive learning style the lowest. It was determined that students with an independent learning style had

			towards English	higher achievement scores, and a moderate positive relationship was found between motivation and academic achievement.
Çağdaş (2023)	11th grade students	Quantitative	11th grade students' approaches to learning mathematics, levels of motivation in mathematics, gender, parents' educational status and school type	Surface learning levels were found to be low and deep learning levels at a moderate level; deep learning levels and mathematics motivation levels were found to differ significantly by school type.
Marougkas, Troussas, Krouska and Sgouropoulos (2023)	Seventeen studies published in the last decade on approaches and methods to learning based on virtual reality technology	Qualitative	Virtual reality technology and approaches to learning	It was revealed that the deep approach to learning is the most frequently used approach together with VR technology.
Ozan, Karabacak, Kızıltas and Küçükoğlu (2017)	Preservice teachers (1st- and 4th-year students)	Quantitative	Learning styles and approaches to learning, gender, university, year of study and department	The deep approach to learning was found to be high; approaches to learning differed significantly by department and gender. Learning styles did not differ by university, gender or year of study.
Gökalp (2013)	University students	Quantitative	Learning styles and academic achievement	As a result of activities administered to students according to their learning styles, a significant difference was found in their academic achievement.
Ozan, Köse and Gündoğdu (2012)	Preschool teaching and primary school teaching students	Quantitative	Gender, department and approaches to learning	A significant difference in the surface approach to learning was observed by gender, and it was found that male students were more likely to adopt a surface approach to learning.

In reviews of the literature on approaches to learning and learning styles, it has been observed that studies are predominantly conducted with preservice teachers at the higher education level, whereas fewer studies have been carried out at the high school level. In the relevant literature, approaches to learning are generally examined together with variables such as socioeconomic status, family background, age, gender, department, achievement, personality and attitudes towards the course, and no study has been found that relates approaches to learning to school type and learning styles at the high school level. In addition, an examination of the nationally implemented curricula shows that subject curricula do not vary according to school type (MEB, 2024). It is known that in different federal states of Germany, different curricula are implemented in line with diverse needs and demands (Doğan, 2020). Considering that the learning process becomes diversified through individual approaches to learning and learning styles, the present study may contribute to the literature by identifying the need for differentiated curricula for individuals with different learning styles and approaches to learning in different types of high schools.

Based on the studies reviewed in the literature, no research has been identified at the high school level that examines learning styles and approaches to learning according to school type. In today's context, where learner-centred and constructivist understandings of education place greater emphasis on research focusing on learners, it is thought that a study addressing these two variables together will contribute to the literature. The individualization of educational processes and the development of programmes that respond to students' diverse learning needs have become among the primary goals of education systems. Understanding students' approaches to learning and learning styles plays a critical role not only in enhancing their academic achievement but also in increasing the effectiveness of teaching–learning processes. By revealing the relationship between high school students' approaches to learning and their learning styles, this study aims to provide the scientific basis needed for the design of curricula. Furthermore, if approaches to learning and learning styles are found to differ according to school type, the importance of developing differentiated curricula for different types of high schools will be underscored.

Although there are many studies in the literature on approaches to learning and learning styles, research that examines the relationship between these two variables in detail specifically for high school students and in terms of school type is limited. This study seeks to address this gap and to guide future research on both approaches to learning and learning styles.

The findings of the research may provide guidance to curriculum developers and education policy-makers in the process of curriculum development. In particular, if significant differences are identified by school

type, it may be suggested that curricula implemented in high schools should be diversified. This is important for the wider dissemination of individualized education and for enabling students to participate more effectively in their learning processes.

The fact that each student has different approaches to learning and learning styles necessitates that curricula be structured in a way that takes individual differences into account. However, the limited number of studies in Türkiye that address high school students' approaches to learning and learning styles in a holistic manner indicates a need for further research in this area. In particular, examining the differences in students' learning processes across different types of high schools may support these school types with programmes designed in line with their educational goals. Therefore, the findings of this study are expected to make significant contributions to the education system, education policies and curricula.

The purpose of this study is to determine the relationship between high school students' approaches to learning and learning styles, to examine whether approaches to learning and learning styles differ according to school type, and to demonstrate to curriculum development authorities the importance of implementing different curricula for different types of high schools. Indeed, in the relevant literature, there is an emphasis on designing agile curriculum (responsive to changing individual, sectoral and societal needs and expectations) that prepare students for the new VUCA world and the professions of the future, in line with global needs and expectations (Derin Kılıç & Küçükoğlu, 2024a).

In line with this purpose, the study seeks to answer the following research questions:

- What are high school students' approaches to learning?
- What are high school students' learning styles?
- Is there a relationship between high school students' approaches to learning and their learning styles?
- Is there a significant difference in high school students' approaches to learning when examined in terms of school type?
- Is there a significant difference in high school students' learning styles when examined in terms of school type?

METHOD

Research Design

The purpose of this study was to reveal the relationship between high school students' learning approaches and learning styles, and to determine whether these variables differ according to the type of high school students attend. In line with the research purpose and sub-questions, a cross-sectional survey design—one of the non-experimental quantitative research methods—was adopted. The cross-sectional survey model is a design in which data are collected within a specific time period and is preferred to describe, analyze, and evaluate an existing situation in a study group as it is (Creswell, 2011). It is used to examine individuals' views, attitudes, approaches, and behaviors in relation to the specified variables (Christensen et al., 2014). The survey model not only presents cases, frequencies, or the distribution of characteristics within a particular sample, but can also be used to examine relationships among variables and causality (Fraenkel et al., 2012; McMillian & Schumacher, 2010).

Sample

The population of the study consisted of 11th-grade high school students in the province of Erzurum. According to statistics released to the public by the Ministry of National Education, the identified population includes a total of 9,692 students—4,924 male and 4,708 female (MEB, 2024). The main reason for selecting 11th-grade students is that, at this level, students choose academic tracks such as quantitative, verbal, and equally weighted (mixed) fields. It was assumed that students would be more purposeful and motivated in their learning approaches and styles after choosing a track, and thus would provide more accurate data during the research process. According to Edwin Locke's goal-setting theory, individuals carry out goal-directed actions with higher motivation (Aslan & Doğan, 2020). Therefore, it was aimed to obtain more accurate data from motivated and goal-oriented individuals. For a research population of approximately 10,000 students, the required sample size was calculated as 370 at a 95% confidence level (Christensen et al., 2014).

Sample selection was determined using an appropriate stratified method. The study group was determined in two stages: first through convenience sampling and then through stratified sampling. Convenience sampling is a method that requires lower cost and provides ease to the researcher in terms of accessibility and time (Creswell, 2011). Stratified sampling, on the other hand, is a sampling method in which the population is divided into subgroups or strata based on certain characteristics, and a specific number of individuals are selected from each stratum. This method is used to ensure that different groups in the population are represented in the sample (Cohen et al., 2016; McMillian & Schumacher, 2010). To ensure data

diversity, five strata were identified: science high schools, Anatolian high schools, social sciences high schools, imam hatip high schools, and vocational high schools; one school from each stratum was selected using convenience sampling. In total, 427 11th-grade students from these five strata participated in the study; however, 39 responses were considered invalid due to missing data and random marking. Demographic information regarding the study sample is presented in Table 2.

Table 2: Demographic Characteristics of the Sample

School	Female		Male		Total	
	N	%	N	%	N	%
SBL[4]	53	%60.9	34	%39.1	87	%20.4
AİHL[5]	52	%54.7	43	%45.3	95	%22.2
FL[6]	51	%45.5	61	%54.4	112	%26.2
AL[7]	55	%59.1	38	%40.9	93	%21.8
ML[8]	0	%0	40	%100	40	%9.4
Total	211	%49.4	216	%50.6	427	%100

No pressure was placed on the participants to complete the scales, and the data were collected entirely on a voluntary basis. Ethical approval and research permissions related to the study were obtained from the relevant institutions.

Data Collection Instruments

In this study, the Grasha–Reichmann Student Learning Styles Scale, adapted into Turkish by Sarıtaş and Süral (2010) with established validity and reliability, and the Approaches to Learning Inventory, adapted into Turkish by Çolak and Fer (2007) with established validity and reliability, were used as data collection tools. Permissions for the use of the scales were obtained from the researchers who carried out the adaptation studies. In addition, a set of demographic questions prepared by the researcher to collect students' demographic information was appended to these measurement tools.

The Grasha–Reichmann Student Learning Styles Scale offers the opportunity to conduct a comprehensive analysis by addressing learning styles under six different categories. In this scale, students are categorized into six learning styles—independent, avoidant, collaborative, dependent, competitive

[4] Social Sciences High School
[5] Anatolian Religious High School
[6] Science High School
[7] Anatolian High School
[8] Vocational High School

and participant—in order to determine their social learning preferences. The scale consists of six sub-dimensions, each comprising 10 items, for a total of 60 items, and is a five-point Likert-type instrument (Sarıtaş & Süral, 2010). Sarıtaş and Süral (2010) carried out the adaptation of the Grasha–Reichmann Student Learning Styles Scale at the higher education level and calculated the Cronbach's alpha reliability coefficient as .802, demonstrating that it is a reliable measurement tool. Dağ and Karamustafaoğlu (2023) administered the scale to a science high school sample and reported an overall reliability coefficient of .809. In the present study, the Cronbach's alpha reliability coefficient was found to be .841. According to Büyüköztürk et al. (2020), if the reliability coefficient is in the range $0.60 < \alpha < 0.80$, the scale can be considered reliable. With the obtained reliability coefficient of 0.841, it was shown that the scale is also a valid and reliable measurement tool at the high school level. For each sub-dimension of the scale, the mean scores obtained were used to classify levels as "low", "medium" and "high" (Sarıtaş & Süral, 2010). Mean scores for the six learning styles were calculated across these three levels. These levels are presented in Table 3.

Table 3: Rating Scheme for the Grasha–Reichmann Student Learning Styles Scale

	Degree of Learning Styles		
Learning Styles	**Low**	**Medium**	**High**
Independent	1.0 – 2.7	2.8 – 3.8	3.9 – 5.0
Avoidant	1.0 – 1.8	1.9 – 3.1	3.2 – 5.0
Collaborative	1.0 – 2.7	2.8 – 3.4	3.5 – 5.0
Dependent	1.0 – 2.9	3.0 – 4.0	4.1 – 5.0
Competitive	1.0 – 1.7	1.8 – 2.8	2.9 – 5.0
Participant	1.0 – 3.0	3.1 – 4.1	4.2 – 5.0

The Approaches to Learning Inventory adapted by Çolak and Fer (2007) was originally developed by Biggs, Kember and Leung in 2004. Students' scores are calculated as the sum of the item scores. The response format is a five-point Likert scale scored as "never true of me (1)", "rarely true of me (2)", "sometimes true of me (3)", "often true of me (4)" and "always true of me (5)".

The inventory consists of a total of 22 items. Eleven of these items are related to deep learning; 7 of them measure the deep motivation dimension and 4 of them measure the deep strategy dimension. The total score range for the deep approach is between 11 and 55. Example items for the deep approach to learning include "I try to relate what I learn about a topic to what I have learned in other topics" and "I consider myself to have learned sufficiently

only when I have studied a topic to the point where I can form my own interpretations".

The other 11 items in the inventory are related to surface learning; 4 of these measure surface motivation and 7 measure the surface strategy dimension. The score range for the surface approach is likewise between 11 and 55. Example items for the surface approach to learning include "The best way to pass exams is to memorize the answers to the questions that are likely to be asked" and "I do not see any need to learn topics that are unlikely to appear in the exam".

In the inventory, the surface approach score is calculated as the sum of the scores obtained from the surface strategy and surface motivation dimensions, while the deep approach score is calculated as the sum of the deep strategy and deep motivation scores. Both the sub-dimension scores and the total scores for the deep and surface approaches can be evaluated separately.

According to the results of the internal consistency analysis, Cronbach's alpha coefficients were found to be 0.79 for the deep approach to learning and 0.72 for the surface approach to learning. These values indicate that the inventory is a reliable measurement tool for both dimensions of approaches to learning (Çolak & Fer, 2007). In the present study, the overall Cronbach's alpha reliability coefficient was calculated as .650. According to Büyüköztürk et al. (2020), if the reliability coefficient is in the range $0.60 < \alpha < 0.80$, the scale can be considered reliable.

Data Analysis

Among the data obtained from 427 students who participated in the study, 39 forms were found to be invalid; thus, the analyses were conducted using 388 valid questionnaires. First, skewness and kurtosis values were examined to determine whether the data were normally distributed, and it was found that all skewness and kurtosis values fell within the range of -1.5 to +1.5. According to Tabachnick and Fidell (2013), skewness and kurtosis values within the range of -1.5 to +1.5 indicate that the data are normally distributed.

Descriptive statistical methods were used to identify high school students' approaches to learning and learning styles. To examine the relationship between students' approaches to learning and their learning styles, the Pearson correlation test was employed. Pearson correlation is a parametric test used to measure the linear relationship between two continuous variables. It is preferred when the variables are normally distributed and when there are no outliers that might distort the relationship (Cohen, 2020).

To investigate whether students' approaches to learning differed according to school type, a MANOVA test was used. MANOVA (Multivariate Analysis of Variance) is a statistical method used to analyse how multiple

dependent variables are simultaneously affected by one or more independent variables. In this study, surface and deep approaches to learning were treated as dependent variables, while school type was treated as the independent variable. When there are linear relationships among the dependent variables, MANOVA provides more powerful and effective results compared to conducting separate ANOVA analyses. This method evaluates the effect of independent variables on the dependent variables while also taking into account the interrelationships among the dependent variables (Tabachnick & Fidell, 2013). For the MANOVA test, the assumption of homogeneity of variances was found to be satisfied ($p = .07$, $p = .68$; $p > .05$).

To examine whether students' learning styles differed according to school type, the chi-square test was employed. The chi-square test is a statistical method used to evaluate the relationship or difference between categorical variables. Since each learning style was categorized as "low", "medium" or "high", the chi-square test was deemed appropriate. This test compares the observed (actual) frequency distribution with the expected frequency distribution. It is widely used particularly in the analysis of categorical data (Field, 2022).

FINDINGS

Findings on Approaches to Learning

The findings regarding high school students' approaches to learning according to school type, together with mean and standard deviation values, are presented in Table 4.

Table 4: Findings on High School Students' Approaches to Learning

		Deep Learning		Surface Learning	
	N	**X**	**S.D.**	**X**	**S.D.**
School Type					
SBL	83	28.96	5.76	35.51	6.87
AİHL	84	29.46	4.63	35.12	6.31
FL	97	28.35	4.75	35.13	5.52
AL	91	29.55	5.40	35.67	5.71
ML	33	27.36	5.69	34.94	6.88
Total	388	28.95	5.19	35.23	6.09

When Table 4 is examined, it is observed that in this assessment conducted with a total of 388 students, students preferred the surface approach to learning more frequently than the deep approach ($M = 35.23 > M = 28.95$). The lower standard deviation value in deep learning strategies ($SD = 5.19$) indicates that the learning behaviours of students who adopt this strategy are more homogeneous. Among those who prefer the deep approach to learning,

Okul Türü		SBL		AİHL		FL		AL		ML			
Öğrenme Stili		**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**V**	**p**
Independent	Düşük	7	%8.3	8	%9.5	11	%11.3	4	%23.1	9	%27.3	.16	012
	Orta	56	%67.9	60	%71.4	69	%71.2	66	**%72.5**	23	%69.7		
	Yüksek	20	%23.8	16	%19	17	%17.5	21	%4.4	1	%3		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Avoidant	Düşük	41	%56	38	%45.2	59	%60.8	40	%44	15	%45.5	.12	220
	Orta	32	%38	42	%50	35	%36.1	47	%51.6	18	%54.5		
	Yüksek	5	%6	4	%4.8	3	%3.1	4	%4.4	0	%0		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Colloborative	Düşük	19	%22.6	16	%19	21	%12.4	22	%24.2	12	%36.4	.15	036
	Orta	56	%67.9	55	%65.5	64	%66	59	%64.8	18	%54.5		
	Yüksek	8	%9.5	13	%15.5	12	%21.6	10	%11	3	%9.1		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Dependent	Düşük	11	%13.1	11	%13.1	13	%13.4	6	%6.6	6	%18.2	.09	710
	Orta	56	%67.9	64	%76.2	78	%80.4	64	%70.3	23	%69.7		
	Yüksek	16	%19	9	%10.7	6	%6.2	21	%23.1	4	%12.1		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Competitive	Düşük	36	%42.9	31	%36.9	49	%50.5	27	%29.7	17	%51.5	.13	.10

	Orta	38	%46.4	48	%57.1	43	%44.3	54	%59.3	14	%42.4		
	Yüksek	9	%10.7	5	%6	5	%5.2	10	%11	2	%6.1		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		
Participant	Düşük	23	%27.4	20	%23.8	30	%30.9	20	%22	15	%45.5		
	Orta	51	%61.9	57	%67.9	63	%64.9	68	%74.7	17	%51.5	.13	082
	Yüksek	9	%10.7	7	%8.3	4	%4.2	3	%3.3	1	%3		
Toplam		83	%100	84	%100	97	%100	91	%100	33	%100		

students attending Anatolian high schools (AL) have the highest mean score (M = 29.55), followed by students in Religious high schools (AİHL; M = 29.46), social sciences high schools (SBL; M = 28.96), science high schools (FL; M = 28.35) and vocational high schools (ML; M = 27.36). In terms of the surface approach to learning, Anatolian high school students (AL) also have the highest mean score (M = 35.42). They are followed respectively by students in social sciences high schools (SBL; M = 35.51), science high schools (FL; M = 35.13), Religious high schools (AİHL; M = 35.12) and vocational high schools (ML; M = 34.94).

Findings on Learning Styles

The findings regarding high school students' learning styles according to school type are presented in Table 5.

Table 5: Findings on High School Students' Learning Styles

A significant relationship was found between the independent learning style and school type (V = .16, p = .01). Among vocational high school (ML) students, a low level of independent learning style is more prevalent (27.3%), whereas 72.5% of Anatolian high school (AL) students have a moderate level of independent learning style. A weak but significant relationship was also identified between the collaborative learning style and school type (V = .15, p = .04). While a high level of collaborative learning style is less common among science high school (FL) students (21.6%), 74.7% of AL students display a moderate level of collaborative learning. For the avoidant learning style, the relationship is weak and not significant (V = .18,

p = .22); however, the low-level avoidant style ratio of 60.8% among FL students is noteworthy. No statistically significant relationship was found between school type and the other learning styles (dependent, competitive, participant) (dependent: V = .08, p = .71; competitive: V = .13, p = .10; participant: V = .13, p = .08). Overall, the most common category of learning styles across all school types is the moderate level. While ML students have higher rates of low-level learning styles and lower rates of high-level styles, FL and AL students display a more balanced distribution at the moderate level, indicating a more homogeneous structure. These findings reveal that there are meaningful differences between school types in terms of learning styles.

Relationship Between High School Students' Approaches to Learning and Learning Styles

To examine the relationship between high school students' approaches to learning and their learning styles, a Pearson correlation test was conducted and the results are presented in Table 6.

Table 6: Correlation Test Results on High School Students' Approaches to Learning and Learning Styles

Variables		N	r	p
Deep Learning Approach	Independent	388	.46	.00
	Avoidant	388	-.15	.03
	Collaborative	388	.43	.00
	Dependent	388	.41	.00
	Competitive	388	.41	.00
	Participant	388	.46	.00
Surface Learning Approach	Independent	388	.14	.067
	Avoidant	388	.29	.00
	Collaborative	388	.08	.00
	Dependent	388	.19	.00
	Competitive	388	.20	.00
	Participant	388	-.05	.007

When Table 7 is examined, it is seen that there are significant relationships between high school students' approaches to learning and their learning styles. The deep approach to learning shows moderate, positive relationships with the independent ($r = 0.46$, $p < .001$), collaborative ($r = 0.43$, $p < .001$), participant ($r = 0.46$, $p < .001$) and competitive ($r = 0.41$, $p < .001$) learning styles. On the other hand, a weak but significant negative relationship was found between the deep approach and the avoidant learning style ($r = -0.15$, $p < .05$). The surface approach to learning displayed a low-level positive relationship only with the avoidant learning style ($r = 0.29$, $p < .01$). No significant relationships were found between the surface approach and the other learning styles. According to Cohen (2020), correlation levels are

classified as low between 0.10 and 0.30, moderate between 0.30 and 0.50, and large between 0.50 and 1.00.

Findings on the Differences in High School Students' Approaches to Learning by School Type

To examine whether high school students' approaches to learning differed according to school type, a MANOVA test was conducted and the results are presented in Table 7. Since deep and surface approaches to learning were treated as separate dependent variables, MANOVA was preferred.

Table 7: Differences in High School Students' Deep and Surface Approaches to Learning by School Type

		Sum of Squares	df	Mean of Squares	F	p	η^2
School Type	Deep Approach	174.31	4	43.58	1.63	.17	.02
	Surface Approach	80.85	4	20.21	.54	.71	.01

When Table 7 is examined, the effect of school type on students' approaches to learning is revealed. It was found that there was no significant difference according to school type in terms of either the deep approach to learning ($F = 1.63$, $p > .05$) or the surface approach to learning ($F = .54$, $p > .05$).

Findings on the Differences in High School Students' Learning Styles by School Type

To examine whether high school students' learning styles differed according to school type, a chi-square test was conducted and the results are presented in Table 8. The preference for the chi-square test was based on the fact that learning styles were categorized as "low", "medium" and "high".

Table 8: Chi-Square Test Results for Differences in High School Students' Learning Styles by School Type

Groups		School Type						X^2	df	p
		SBL	AİHL	FL	AL	ML	Toplam			
Independent	Low	7	8	11	4	9	39	19.55	8	.012
	Med	56	60	69	66	23	274			
	High	20	16	17	21	1	75			
	Total	83	84	97	91	33	388			
Avoidant	Low	46	38	59	40	15	198	10.74	8	.22
	Med	32	42	35	47	18	174			
	High	5	4	3	4	0	16			
	Total	83	84	97	91	33	388			
Dependent	Low	11	11	13	6	6	47	16.45	8	.036
	Med	56	64	78	64	23	285			
	High	16	9	6	21	4	56			
	Total	83	84	97	91	33	388			
Collaborative	Low	19	16	21	22	12	90	5.44	8	.71
	Med	56	55	64	59	18	252			
	High	8	13	12	10	3	46			
	Total	83	84	97	91	33	388			
Competitive	Low	36	31	49	27	17	160	13.38	8	.10
	Med	38	48	43	54	14	197			
	High	9	5	5	10	2	31			
	Total	83	84	97	91	33	388			
Parti.	Low	23	20	30	20	15	108	14.00	8	.082

Med	51	57	63	68	17	256
High	9	7	4	3	1	24
Total	83	84	97	91	33	388

When Table 8 is examined, it is seen that there is a significant difference in the independent learning style according to school type (X^2 = 19.55, p = 0.012). This finding indicates that the levels of the independent learning style (low, medium, high) differ across school types. It is noteworthy that the independent learning style is more frequently observed at a high level among social sciences high school and science high school students, whereas this level is lower among vocational high school students.

For the dependent learning style, a significant difference was also found according to school type (X^2 = 16.45, p = 0.036). This result shows that the levels of the dependent learning style (low, medium, high) vary across different school types. While Anatolian high school students tend to display a high level of dependent learning style, vocational high school students appear at lower levels.

No significant difference by school type was found for the avoidant learning style (X^2 = 10.74, p = 0.22), the collaborative learning style (X^2 = 5.44, p = 0.71), the competitive learning style (X^2 = 13.38, p = 0.10) or the participant learning style (X^2 = 14.00, p = 0.082).

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

In this study, high school students' learning styles, approaches to learning and their differences according to school type were examined. According to the findings, no significant difference was found in approaches to learning by school type. Students predominantly adopted a surface approach to learning across all school types (M = 5.23). This indicates that high school students tend to prefer more rote-based and surface-oriented strategies in their learning processes. The higher standard deviation for surface learning strategies (SD = 6.09) shows that individual differences are more pronounced among students who use this strategy.

These findings are in line with the study by Yazıcı and Kartal (2020), who examined the approaches to learning of students attending different types of high schools. In their research, it was concluded that approaches to learning did not differ significantly by school type and that students more frequently preferred surface learning strategies. Similarly, the present results are consistent with those of Dikbayır's (2016) study on high school students' learning strategies. Dikbayır reported that school type had no significant effect

on learning strategies and that individual differences were spread across a wider spectrum. In particular, differences between individuals in surface learning strategies were highlighted as being associated with factors such as students' motivation and their perceptions of the learning process. Moreover, the wider distribution of surface learning in certain school types such as vocational high schools (ML) suggests that students in these groups exhibit a more heterogeneous structure in their learning processes. In contrast, the narrower range of individual differences among Anatolian high school (AL) students may point to a more homogeneous structure in their learning processes.

However, in the studies by Çağdaş and Ekinci (2024), which examined deep and surface approaches to learning in the context of mathematics, it was found that students adopted the deep approach more than the surface approach. This discrepancy may stem from factors such as differences in the research sample, the scales used or the subject area examined. In a similar study, Nar (2024) identified significant differences in favour of the deep approach in middle school students' approaches to learning in social studies, both overall and by grade level. In addition, another study by Kartal and Yazıcı (2020) showed that approaches to learning may differ by grade level, suggesting that, although not necessarily dependent on school type, approaches to learning can be influenced by socioeconomic environment, gender and curricula. The findings of Biggs and Tang (2011), which associate the prevalence of surface learning with lack of motivation and inappropriate learning environments, are also compatible with the present study. This indicates that more effective pedagogical strategies are needed to support high school students' learning processes. In today's rapidly changing and evolving world, there is a growing momentum towards changing educational paradigms to equip people to cope with new and uncertain challenges. It is considered necessary to utilise experiential learning designs in the context of encouraging students to become lifelong learners, to derive meaning from their experiences, and to engage in collaborative learning (Derin Kılıç, Er & Küçükoğlu, 2024).

In this context, the fact that the learning process is shaped by individual approaches to learning and learning styles points to the need for curricula to be diversified in a way that is responsive to each learner's needs. Individualised approaches to learning processes in different types of schools can not only help students develop strategies appropriate to their learning styles but also encourage them to adopt deeper approaches to learning. In conclusion, while the finding that approaches to learning differ by school type is supported by some studies, it is not supported by others. These contradictory results suggest that approaches to learning are shaped by a range of factors such as individual characteristics, curricula and environmental conditions, and that more comprehensive research is needed in this area. As it is known, the

"one-size-fits-all" approach in institutions is generally unsuitable for both individual and societal needs. It is now widely accepted that the concept of flexibility is closely linked to the concept of choice. This is because it is known that offering students flexible choices in terms of experiencing different learning experiences facilitates individualisation (Derin Kılıç & Küçükoğlu, 2024b).

Despite the school-type variable, the similarity in surface learning tendencies indicates that the current education system directs students towards rote-based and surface strategies. This underlines the need to restructure curricula in a way that supports students' adoption of deep approaches to learning. It is known that the curricula implemented at the 11th grade level are those introduced in 2018 (MEB, 2018). The fact that students in all school types that admit students with different achievement levels through the LGS examination adopt a surface approach suggests that students tend to prefer exam-oriented, rote and short-term learning (Aktunç, 2023; Teoh & Yap, 2015). Yet it is well established that students who adopt a deep approach achieve more detailed, understanding-based and long-term learning (Alkhateeb & Bani-Milhem, 2020; Arslan, 2017). Eğmir and Çelik (2021), in their study on the education system, also drew attention to its rote-oriented nature. In this context, self-regulation strategies that can help students succeed at school and in life: (a) organising the environment in terms of movement, (b) setting expectations, (c) teaching problem-solving approaches, (d) teaching strategies on what to do when waiting for help, (e) preparing signals for requesting help, (f) teaching students to pause and reflect and to plan, (g) teaching organisational skills, (h) dealing with disagreements, (i) providing motivation, (j) teaching students self-monitoring skills (Kılıç & Melekoğlu, 2018).

The finding that high school students' learning styles differ by school type suggests that learning styles may be related to the type of school attended. For example, the independent learning style is more frequently observed in certain school types, while it is less preferred in others. The avoidant learning style is not observed at all in some types of schools, whereas it appears at lower levels in others. In the collaborative learning style, some school types show a balanced distribution, while in others there is a concentration at low levels. These findings support the significant relationship between high school type and learning styles reported in the study by Çakır and Akbaş (2013). In that study, it was noted that students predominantly adopted the independent learning style and that school type had an effect on this preference. However, the studies by Yıldız (2017) and Zencir (2024) reported that learning styles did not generally differ significantly by school type, but were more strongly associated with individual characteristics and environmental factors.

Similarly, Azarkhordad and Mehdinezhad (2016) found that dependent and participant learning styles were generally dominant, but that independent and avoidant styles came to the fore depending on gender. Dağ and Karamustafaoğlu (2023) reported that science high school students predominantly adopted competitive and collaborative learning styles. One of the most effective ways to deliver course content is to develop note-taking skills. Developing note-taking skills is considered quite important in terms of ensuring learning. Therefore, taking notes during lessons is important for all students, regardless of any type of disability (Kılıç & Melekoğlu, 2018a). The variety of findings in the literature indicates that learning styles can be influenced by variables such as school type, environment, research context and gender, and that these variables play an important role in learning processes.

Significant relationships were also identified between high school students' approaches to learning and learning styles. The deep approach to learning showed moderate, positive relationships with independent, collaborative, participant and competitive learning styles, and a weak but significant negative relationship with the avoidant learning style. The surface approach, on the other hand, displayed a low-level positive relationship only with the avoidant learning style and no significant relationship with the other styles. These findings support the meaningful relationship between learning styles and learning strategies reported by Güven (2004). In that study, it was emphasised that students with certain learning styles more frequently used strategies consistent with those styles. This underscores the importance of individual tendencies in students' learning processes. However, in Yıldız's (2017) study, no significant relationship was found between learning styles and approaches to learning. These discrepancies suggest that learning processes may be influenced by both individual and environmental factors.

The correlation analyses revealed positive relationships between the deep approach to learning (associated with higher-order learning skills) and the independent (self-directed), collaborative (interaction-oriented) and participant (keen to share/teach knowledge and ideas) learning styles. These findings indicate that students who adopt a deep approach to learning tend to have a more interaction-oriented and analytical way of thinking (Çolak & Fer, 2007; Sarıtaş & Süral, 2010). In addition, Çolak (2015) found a relationship between students who prefer deep approaches to learning and those who adopt collaborative and competitive learning styles. The fact that the avoidant learning style (characterised by withdrawal from learning and interaction) shows a weak negative relationship with the deep approach suggests that this style may be associated with more passive and surface learning strategies (Aktunç, 2023; Dağ & Karamustafaoğlu, 2023). These findings highlight the need to redesign school curricula and learning environments to support students' adoption of deep approaches to learning. Furthermore, future

research with different age groups and educational levels is recommended to gain a better understanding of the relationships between learning styles and approaches to learning.

The MANOVA and chi-square analyses revealed that the effect of school type on approaches to learning and learning styles is limited. However, the significant differences found in independent and dependent learning styles suggest that these style categories are more sensitive to school climate. This finding is consistent with studies that argue that learning styles can be influenced by individual differences and environmental factors. For example, Eğmir and Çelik (2021) emphasised that students' approaches to learning are sensitive to individual and environmental factors. Similarly, another study showed that learning styles can differ significantly by high school type and that female students tend to be more dependent and collaborative learners than male students (Yılmaz & Keleşoğlu, 2014). In Öztekin's (2012) study, learning styles of students from different types of high schools were examined and found to differ according to school type; it was also determined that female students were more likely to have dependent and collaborative styles than male students.

In the systematic review conducted by Cevher (2017), academic studies on learning styles were examined and the relationships between learning styles and various variables were discussed. This review concluded that learning styles are influenced by individual differences, but did not find clear evidence regarding the effect of school type. Nevertheless, some studies report findings that contradict these results. For instance, in a study by Demir et al. (2019), significant differences were found in approaches to learning across different school types. This suggests that the effect of school type on approaches to learning is not entirely limited and that a more complex relationship may be at play. Moreover, a systematic review on learning styles indicated that they are influenced not only by individual characteristics but also by environmental factors (Kaya, 2020). In conclusion, although the significant differences found in the independent and dependent learning style categories suggest that these styles may be more sensitive to school climate, the boundaries of school-type effects and the other factors involved in this relationship need to be examined more comprehensively.

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Procrastination Behaviors And Psychological Resilience of Adult Individuals

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ABSTRACT

This study examines the relationship between procrastination behaviors and psychological resilience in adults, as well as whether these behaviors differ in terms of demographic variables. The research was conducted on 303 employed adults, selected through criterion sampling. Data were collected using a demographic information form, the Short Procrastination Scale, and the Adult Psychological Resilience Scale. Analyses revealed that female had significantly higher procrastination tendencies compared to male. A significant difference was observed in terms of educational level; individuals with postgraduate education had higher procrastination scores than other groups. It was determined that individuals without children exhibited more procrastination behaviors compared to those with children. In terms of years of employment, it was found that as the duration of employment increased, the tendency to procrastinate decreased. A negative and significant relationship was found between procrastination and psychological resilience, with the psychological resilience variable explaining 11.7% of the variance in procrastination behaviors. These findings suggest that interventions aimed at enhancing individuals' psychological resilience may be effective in reducing procrastination behaviors.

Keywords: Procrastination Behaviors, Psychological Resilience, Working Adults, Procrastination Tendency, Procrastination Level

INTRODUCTION

Procrastination is known as the deliberate postponement or deferral of responsibilities by individuals until the last moment (Uzun Özer, 2009). According to Roberts (1997), procrastination behavior can be explained as prioritizing short-term gains over long-term benefits. In general, procrastination behaviors is associated with unnecessary delays in completing tasks, which often lead to discomfort. Milgram et al. (1998) define procrastination behaviors as a personality trait that causes delays in decision-making processes or task execution.

The causes of procrastination behaviors may involve individual, environmental, and psychological factors. Procrastination behaviors can be triggered by individual characteristics such as low self-regulation skills, time management problems, and perfectionism (Klassen et al., 2008). Moreover, seeking immediate emotional comfort at the cost of long-term objectives can sustain procrastination behaviors (Sirois & Pychyl, 2013). Environmental factors include situations where the social environment encourages procrastination behaviors, as well as heavy workloads or task ambiguity. Psychologically, low self-confidence, anxiety disorders, and lack of motivation are frequently associated with procrastination behaviors (Steel, 2007).

Procrastination behaviors often negatively affects individuals' academic achievements. It was indicated by Tice and Baumeister (1997) that the student who has procrastination habits faces low level of academic achievement, primarily as a result of increased stress levels. Additionally, this behavior can diminish self-esteem and reduce quality of life (Ferrari et al., 2005). According to Wadkins (1999), procrastination behaviors may lead to dropping out of classes, low academic performance, prolonged study periods, and even leaving school. Research suggests that procrastination behaviors may be influenced by demographic factors, including gender, age, marital status, and income level. For instance, the study by Ferrari et al. (2005) revealed that males exhibit higher tendencies toward procrastination behaviors compared to females. Furthermore, Sirois and Pychyl (2013) noted that this relationship can vary across cultural and social contexts.

The term psychological resilience originates from the Latin word "resiliens." This concept, rooted in mathematics and physics, is defined as a material's ability to return to its original equilibrium after undergoing changes (Greene, 2002). The strategies people use to cope with stress and challenging situations vary from person to person. In this context, the critical aspect is the meaning individuals attribute to events and the behaviors they develop in response. If the responses are sufficiently robust and offer diverse alternatives, the likelihood of effectively coping with such situations increases (Yağmur & Türkmen, 2017). Studies show that protective factors are essential in fostering psychological resilience. These factors include

social relationships, family support, positive self-perception, and problem-solving skills. For instance, Masten and Obradovic (2006) stated that psychological resilience is a dynamic process shaped by interactions with one's environment. Enhancing individuals' positive coping skills strengthens their psychological resilience. Research emphasizes the significance of protective elements like family backing, robust social ties, self-confidence, problem-solving skills, and a hopeful outlook (Rutter, 1987). A study carried out in Turkey revealed that social support systems greatly influence psychological resilience (Arslan, 2015a).

Psychological resilience enhances a person's capacity to handle challenges and aids in reducing mental health problems like stress, anxiety, and depression (Bonanno, 2004). High levels of psychological resilience support individuals in making healthier decisions and maintaining emotional balance during crises. Therefore, interventions aimed at enhancing psychological resilience play an important role in improving individuals' standard of living. Internationally, Seligman (2011) addressed psychological resilience as a sub-branch of positive psychology and associated this concept with individuals' optimism, happiness, and strengths. In addition, Ungar (2011) examined the effects of cultural context on psychological resilience and emphasized both cultural and universal components of this concept. Present study aimed to determine procrastination levels of working adults in terms of several variables such as gender, educational status, income level, years of employment, marital status, and having children and level of relationship between procrastination behaviors and psychological resilience levels of working adult individuals. Following questions were determined in this direction.

1- Are there significant correlations between their procrastination behaviors and psychological resilience levels of working adults?

2- Do the level of procrastination behaviors of working adults significantly differs with regard to gender, educational status, income level, years of employment, marital status, and having children?

METHOD

Current study was conducted using the general survey model. The study examined whether procrastination behaviors significantly differs with regard to gender, educational level, income status, years of employment, marital status, and having children and if there exist significant relationships between procrastination behaviors and psychological resilience level regarding working adult individuals. The general survey model is known as a design aimed at reaching a general judgment about a population composed of a large number of elements, either entirely or partially, through surveys conducted on samples or subgroups (Karasar, 2005).

Study Group

This study was conducted with adults employed in various occupations. The study included a total of 303 participants. Convenience sampling, a non-random sampling technique, was used for the selection of participants. This technique is a kind of sampling method where the researcher selects individuals who are available, voluntary, and easily accessible within the population (Johnson and Christensen, 2014). In this study, the participants were determined from working adult individuals. Demographic distributions of the study group were displayed in Table 1.

Table 1. Distribution of Study Group Characteristics

Demographic Characteristics	Groups	n	%
Gender	Female	191	63.0
	Male	112	37.0
Educational Status	Primary School	2	0,6
	Middle School	0	0
	High School	32	10,5
	Associate Degree	35	11,5
	Bachelor's Degree	178	58,7
	Postgraduate	56	18,5
Year of Employment	0-5	97	32.0
	6-10	58	19.1
	11-15	61	20.1
	16 or More	87	28.7
Income Level	Low	42	13.9
	Medium	245	80.9
	High	16	5.3
Marital Status	Single	80	26.4
	In a Relationship	23	7.6
	Engaged	11	3.6
	Married	189	62.4
Having children status	Yes	151	49.8
	No	152	50.2

Upon reviewing Table 1, it is noted that 303 individuals took part in the study, with 191 being female and 112 male. Concerning the variable of educational attainment, 2 individuals indicated they finished primary school, 32 completed high school, 35 earned an associate degree, 178 received an undergraduate degree, and 56 obtained a postgraduate degree. The table further indicates that no participants claimed to have finished middle school. Upon examining the work experiences of the participants, it is seen that 97 have 0–5 years, 58 have 6–10 years, 61 have 11–15 years, and 87 have 16 years or more of work experience. Regarding income levels, 42 participants identified their income level as low, 245 as medium, and 16 as high. When examining participants' marital status, it was found that 80 were single, 23 were in a relationship, 11 were engaged, and 189 were married. Additionally,

151 participants reported having children, while 152 participants indicated that they did not have children.

Data Collection Tools

Demographic Information Form: This form included questions regarding age, years of employment, gender, income level, educational status, marital status, and having children. Voluntary participants replied the questions for providing informations about their level of education, income level, age, marital status, gender, work experience in years, and whether they have children. Responses to each of these questions were collected from voluntary participants.

Procrastination Behavior Scale: This one-dimensional 16-item scale developed by Tuckman (1991) was used to measure procrastination behaviors. The validity and reliability study of its Turkish language form was conducted by Karacaoğlu and Kaplan (2013). It was found that the factor loadings of the 16-item unidimensional scale ranged from 0.51 to 0.74 as a result of exploratory factor analysis, and that the factor loadings varied between 0.52 and 0.89 as a result of confirmatory factor analysis. The alpha reliability coefficient of the scale was calculated as 0.87.

Psychological Resilience Scale: The Adult Psychological Resilience Measure was developed based on the Child and Youth Resilience Measure (Arslan, 2015b; Ungar & Liebenberg, 2011) as an adult version (Resilience Research Centre, 2013). The scale was initially translated into Turkish language by the researcher and then back-translated into English by three faculty members specializing in Educational Sciences. These translations were compared by another faculty member fluent in both languages, and the last version of the scale was prepared based on these evaluations. As part of the language validity studies, the correlation between the original form of the measurement tool and its Turkish version was determined to be .82. The scale employs a five-point Likert structure, ranging from “Describes me completely (5)” to “Does not describe me at all (1).” Increasing scores of the scale show increasing level of psychological resilience in individuals (Arslan, 2015a).

Data Analysis

The information gathered from the scales was examined with SPSS statistical software package. Demographic informations regarding the participants was collected via personal information form. The demographic data were coded into SPSS. Total scores obtained from the two scales were also coded into SPSS. The Procrastination Behavior Scale and Adult Psychological Resilience Scale were utilized in this resarch. The findings concerning the comparison of procrastination behaviors scores by gender and parental status were examined using the Independent Samples t-Test.

The data concerning procrastination behavior levels based on educational status, years of employment, income level, and marital status were tested using One-Way Variance Analysis (ANOVA). The Correlation Analysis of Pearson Product-Moment was utilized to ascertain statistically significant relationships between participants' procrastination behaviors and their level of psychological resilience. The findings of the Regression Analysis concerning the prediction of procrastination behaviors by psychological resilience were derived from a Simple Regression Analysis.

FINDINGS

This section includes findings of the statistical analyses applied for present study. T-test was carried out to examine if there is differences about procrastination behaviors in terms of gender variable. These findings are displayed in Table 2.

Table 2. Findings of t-Test About Scores of Procrastination With Regard to Gender Variable

Variable	Group	N	X	SD	t test		
					t	df	p
Gender	Females	191	21.53	7.52	2.479	301	.014
	Males	112	19.40	6.69			

Upon reviewing Table 2, it can be seen that the average procrastination behaviors score for females is 21.53, whereas the average for males is 19.40. The findings of t- Test suggest that the procrastination behaviors of participants differed significantly according to gender [$t(301) = 2.47$; $p < .014$]. According to these findings, it can be inferred that significant difference exists about procrastination behaviors with regard to gender, with females exhibiting substantially higher level of procrastination behaviors than that of males. A one-way ANOVA was performed to assess whether procrastination behaviors scores differed with regard to the educational level. Its findings were displayed in Table 3.

Table 3. Findings of Anova Regarding Scores of Procrastination According to Educational Status

Educational Status	N	X	Sd	Sources of Variance	Sum of Squares	df	Mean Square	F	P	Significance
Primary School	2	15.50	.70	Between Groups	779.576	4	194.894			
High School	32	17.53	5.68	Within Groups	15257.857	298	51.201			
Associate Degree	35	18.74	5.65	Total	16037.432	302		3.81	.005	
Bachelor's Degree	178	21.14	7.47							
Postgraduate	56	22.75	.73							
Total	303	20.74	.28							

Upon examining Anova findings in Table 3, The p-value was analyzed and found to be significant at .005, which indicated significant difference regarding procrastination behaviors according to educational status. Post hoc analyses were performed to determine the particular group where the difference was significant. The F-value of 3.81, obtained for the variance between means, was found to be significant at the .005 level. The findings reveal that individuals with a postgraduate degree have higher procrastination behaviors scores compared to those in other educational levels.

Table 4. Tukey Test Findings For Procrastination Scores According To Educational Status

Variable	Educational Status	Mean Difference	SD	p
Primary Schools	High Schools	-2,03125	5,21541	.995
	Associate Degree	-3,24286	5,20224	.971
	Bachelor's Degree	-5,64607	5,08803	.801
	Postgraduate	-7,25000	5,14925	.623
High Schools	Primary Schools	2,03125	5,21541	.995
	Associate Degree	-1,21161	1,75012	.958
	Bachelor's Degree	-3,61482	1,37393	.067
	Postgraduate	-5,21875*	1,58566	.010

Associate Degree	Primary Schools	3,24286	5,20224	.971
	High Schools	1,21161	1,75012	.958
	Bachelor's Degree	-2,40321	1,32307	.366
	Postgraduate	-4,00714	1,54181	.073
Bachelor's Degree	Primary Schools	5,64607	5,08803	.801
	High Schools	3,61482	1,37393	.067
	Associate Degree	2,40321	1,32307	.366
	Postgraduate	-1,60393	1,09633	.587
Postgraduate	Primary Schools	7,25000	5,14925	.623
	High Schools	5,21875*	1,58566	.010
	Associate Degree	4,00714	1,54181	.073
	Bachelor's Degree	1,60393	1,09633	.587

The findings of Anova for participants' scores of the procrastination behaviors with regard to the years of employment were displayed in Table 5.

Table 5. Findings of Anova Analysis For Levels of Procrastination With Regard to Year of Employment

Years of Employment	N	X	Sd	Sources of Variance	Sum of Squares	df	Mean Square	F	Significance p
0-5	97	22,14	7.49	Between Groups	820.689	3	273.563	5.375	.001
6-10	58	22,41	7.78	Within Groups	15216.743	299	50.892		
11-15	61	20,18	7.26	Total	16037.432	302			
16 and above	87	18,47	6.10						
Total	303	20,47	7.28						

Upon reviewing findings of Anova in Table 5, p-value was found to be .001 and it was determined that significant difference exists regarding procrastination behaviors with regard to years of employment. Post hoc analyses were performed to determine which group showed a significant difference and The F-value of 5.375 was determined as significant at the .001 level.

Table 6. Tukey Test Results for Procrastination Scores In Terms of Years of Employment

Variable	Years of Employment	Mean Difference	Sd	p
0-5	6-10	-.26946	1.18411	.996
	11-15	1.96400	1.16574	.334
	16 or more	3.67307*	1.05339	.003
6-10	0-5	.26946	1.18411	.996
	11-15	2.23347	1.30834	.322
	16 or more	3.94253*	1.20930	.007
11-15	0-5	-1.96400	1.16574	.334
	6-10	-2.23347	1.30834	.322
	16 or more	1.70906	1.19133	.479
16 or more	0-5	-3.67307*	1.05339	.003
	6-10	-3.94253*	1.20930	.007
	11-15	-1.70906	1.19133	.479

When examining the post hoc test results for procrastination behaviors according to years of employment variable, it has been noted that significant difference exists between individuals who have been employed for 0-5 years and those who have been employed for 16 years or longer. Likewise, significant difference were seen between participants with 6-10 years of experiences and those with 16 years or more. Anova Analysis was performed to determine if the participants' procrastination behaviors scores have significant differences with regard to their income levels and its findings were displayed in Table 7.

Table 7. Findings of Anova Analysis for Levels of Procrastination With Regard to Income Level

Income Levels	N	X	Sd	Sources of Variance	Sum of Squares (SS)	df	Mean Square (MS)	F	p	Significance
Low	42	17,64	4.81	Between Groups	93.517	2	46.758			
Medium	245	19,11	4.37	Within Groups	6008.193	300	20.027	2.335	.099	
High	16	17,87	5.11	Total	6101.710	302				
Total	303	18,84	4.49							

When Table 7 were examined, p-value was found to be .099 and there were insignificant differences regarding procrastinations with regard to income level variable. However, upon reviewing the table, it was observed that the mean scores of procrastination behaviors regarding participants with a medium income level ($\bar{X}$ = 19.11) are higher compared to other groups.

Anova Analysis was performed to determine if the participants' procrastination behaviors scores differ significantly with regard to their marital status and its findings are displayed in Table 8.

Table 8. Findings of Anova For Procrastination Levels With Regard to Marital Status

Marital Status	N	X	Sd	Source of Variance	Sum of Squares	Df	Mean Square	F	p	Significance
Single	80	18.43	4.31	Between Groups	97.208	3	32.403	1.614	0.186	3-1
In relationship	23	17.30	4.63	Within Groups	6004.501	299	20.082			
Engaged	11	18.45	5.18	Total	6101.710	302				
Married	189	19.22	4.49							
Total	303	18.89	4.49							

When Table 8 is examined, p-value was found to be .186 and there were insignificant differences regarding procrastination behaviors with regard to marital status. However, upon examining the table, it was seen that the mean scores of procrastination behaviors of married individuals ($\bar{X}$ = 19.22) are higher compared to other groups. T-test was performed to determine if the participants' procrastination behaviors levels vary with regard to having children status and its findings were displayed in Table 9.

Table 9. T-test Findings For Procrastination Level With Regard to Having Children Status

Variable	Group	N	X	SD	t test		
					t	df	p
Having Children	Yes	151	19.05	6.55	-4.119	301	0.003
	No	152	22.42	7.60			

Upon reviewing Table 9, findings indicated that participants' procrastination behaviors significantly differ according to having children status ($t(301) = -4.11$, $p < .003$) and that the mean of procrastination score of individuals who do not have children ($\bar{X}$ = 22.42) are higher compared to that of those who have children. Correlation analysis was utilized to assess if significant relationships existed between participants' procrastination behaviors and their psychological resilience levels and its findings were desplayed in Table 10.

Table 10. Findings of Correlation Between Procrastinations And Psychological Resilience Levels

	Procrastination	Resilience
Procrastination	1	-.343**
Resilience		1

** P < 0.01 level.

The findings of correlation in Table 10 reveals a significant and negative association between participants' procrastination behaviors and their psychological resilience level ($r = -.343$; $p < .01$). This finding suggests that as procrastination behaviors increase, psychological resilience tends to decrease. Conversely, as procrastination behaviors decrease, psychological resilience levels increase. The findings from the regression analysis on how psychological resilience predicts procrastination behaviors are outlined in Table 11.

Table 11. Findings For Predicting Procrastination Behaviors By Psychological Resilience

Variable 1	Variable 2	B	Std. Error	(β)	t	p	R	R^2	F	p
Resilience	Procrastination	-.222	.035	-.343	-6.326	.001	.343	.117	40.013	.001

*p<0.01

The findings of regression analysis about predicting the relationship are shown in Table 11. According to the table, the regression model is significant as the significance level is $p < .001$. The R^2 value, indicating the model's explanatory strength, was computed as .11 ($R = .343$; $R^2 = .117$; $p < .001$). This value indicates that 11.7% of the variance in procrastinations level scores was explained by the independent variable in the model, namely psychological resilience. The Beta coefficient of first variable included in the regression model was found to be $\beta = -.343$.

4. RESULTS, DISCUSSIONS AND RECOMMENDATIONS

The findings of current research indicated that participants' procrastination behaviors level have significant differences with regard to gender. The mean scores for academic procrastination in female were observed to be higher than those in men. It was determined that female's procrastination mean scores were significantly different from those of male.

In contrast, the study by Balkıs et al. (2006) regarding university students indicated that male students exhibited greater procrastination behaviors than their female counterparts. This finding implies that males experience greater challenges in time management and motivation. Similarly, Akbay and Gizir's (2010) study indicated that male participants exhibited higher procrastination behaviors than that of their female counterparts. Furthermore, another study indicated non significant differences in behaviors of procrastination with regard to gender; however, it was revealed that exam anxiety of female students were higher than that of their male counterparts (Özer & Topkaya, 2011). The findings of several researches suggested that there was significant differences regarding procrastination according to number of employment years and that individuals with fewer years of service had higher mean scores of procrastination behaviors compared to others. For example, findings of the research carried out by Balkıs and Duru (2009), supported findings of present study and revealed that teachers with longer professional experience exhibited reduced procrastination behaviors. These research results suggest that as individuals gain experience, their time management skills improve, and procrastination behaviors decrease. Similarly, in the study by Çakıcı (2003), it was found that as years of service increased, procrastination behaviors decreased and that experienced teachers are more successful in completing their tasks on time.

Morover, the findings of present study showed significant differences regarding procrastination behaviors according to educational levels and that participants with postgraduate degrees exhibited higher scores of procrastination behaviors than those with other educational levels. Additionally, current research indicated that the year of study significantly influenced procrastination behaviors, showing that freshmen demonstrated greater procrastination behaviors than upperclassmen. This finding suggests that as students progress through their educational processes, their time management and sense of responsibility improve. In the research performed by Çelikkaleli and Akbay (2013), it was noted that when analyzing the procrastination behaviors regarding university students, their procrastination behavior did not differ significantly with regard to their type of secondary education they completed. The results of a study by Çakıcı (2003), comparing the procrastination behaviors of high school and university students, indicated that university students exhibited greater behaviors of procrastination than high school students, which supports findings of current study. This finding can be associated with university students having more freedom as well as increased responsibility for managing their own learning processes.

Another study indicated that male high school and university students exhibited higher level of procrastination behaviors (Çıkrıkçı & Erzen, 2016). Furthermore, findings of current study determined that procrastination

behaviors level of particpants did not differ significantly with regard to income level. Balkıs and Duru (2009) investigated the procrastination behaviors levels of prospective teachers with regard to their income levels. The results of their research demonstrated that individuals with lower income levels had higher procrastination behaviors. This suggests that economic difficulties may negatively impact individuals' motivation and time management skills. Similarly, results of the study conducted by Çakıcı (2003), indicated that children from families with lower socioeconomic status exhibited higher procrastination behaviors and that economic conditions may exert a substantial influence on individuals' performance.

In addition, the findings of current research suggest that there are non significant differences regarding procrastination behaviors level with regard to marital status. In a supporting study, Uzun (2016) found non significant differences concerning procrastination behaviors with regard to marital status. However, findings of this research indicate that participants' procrastination behaviors exhibited significant differences related to the variable of parenthood. Individuals without children had higher mean scores of procrastination behaviors compared to that of those with children. An additional noteworthy finding of present research showed that 11.7% of the variation in procrastination behaviors scores is accounted for by the psychological resilience.

Moreover, the findings revealed low level of negative correlations between procrastination behaviors and adults' level of psychological resiliences and that as procrastination behaviors rise, individuals' psychological resilience decreases, and as procrastination behaviors decrease, individuals' psychological resilience levels improve. Supporting these findings, a study by Bozan Işık (2019) revealed a low and negative relationship between students' procrastination behaviors and psychological resilience levels.

Current study is limited to adult working individuals. Therefore, studies involving larger sample groups can be conducted. Additionally, similar researches can be carried out on individuals from various occupational groups, age ranges, and socioeconomic levels. It is also suggested to conduct experimental studies assessing the impact of interventions designed to improve psychological resilience on procrastination behaviors. Furthermore, comparative researches investigating how the correlations between procrastination behaviors and level of psychological resilience differ across different cultures can be proposed. By utilizing qualitative research methods, in-depth insights into participants' procrastination behaviors and perceptions of psychological resilience can be obtained. Alternatively, researches on procrastination behaviors and psychological resilience may be carried out utilizing both qualitative and quantitative medhod.

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An Investigation into Expenditure on Education, Class Characteristics and Educational Attainments: Türkiye vs Finland

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ABSTRACT

This study aimed to compare the education systems of Finland and Türkiye, two OECD countries, in an input-process-outcome context, in terms of several indicators from the Education at a Glance 2025: OECD Indicators report. The indicators chosen in line with the input-process-outcome framework for this document analysis study included *expenditure on education* as an input variable while *class characteristics (class size and ratios)* and *educational attainments* of the adults as a process and outcome variable subsequently. Results from the analyses revealed that Finland allocated more money and had higher expenditure rate as a percentage of GDP than Türkiye. When class characteristics were examined, it was seen that classes were more crowded and student-to-teaching staff ratio was higher in Türkiye compared to Finland. It was also found that tertiary educational attainment rate of adults in Finland was much higher than those in Türkiye. Furthermore, the results showed that students in Türkiye tended to end their education journey by the time they completed below upper secondary level of education. For Finland, as a success country in the ratings of overall success for sustainable development and OECD performance indicators and as a country whose students holding high profiles in international exams, educational expenditure appeared to lead to the emergence of better educational processes and outcomes than Türkiye. Accordingly, countries like Türkiye with a potential to develop their educational systems, can pay more attention to improve the variables that could be categorized as inputs or drives of the other mechanisms in their educational systems.

Keywords – Education systems, comparison of education systems, OECD report, Türkiye, Finland.

INTRODUCTION

UNESCO (2025) defines education as a complicated system that has many interrelated stakeholders and subsystems, and states that any change in one component at a certain education level brings alternations in other elements and subsystems. This mutual dependence necessitates that decision makers and policymakers establish consistent and coherent education policies and strategies that incorporate systematic and sectoral viewpoints (UNESCO, 2025). These remind authorities that in the planning process of everything related to education, additional attention and care are required. However, according to United Nations (2025a), 272 million youth and children were excluded from educational institutions in 2023 and compared to 3% in high-income countries, 36% education-age youth and children in

low-income countries deprived of access to school. Considering these pieces of data, it is evident that efficient and urgent steps should be taken in order to achieve Sustainable Development Goal 4: Quality Education. United Nations (2025b) clearly states that Goal 4 is seen as the key goal which will help to the realization of the other goals, and it is emphasized that with quality education people can escape from poverty cycle, inequalities will be reduced and tolerance between people will be fostered, so that more peaceful societies will be formed. Therefore, United Nations specifically stressed that in order to achieve quality education, investments in education must be a priority for a country, education must be free and mandatory, essential school infrastructure should be improved, and more teachers need to be employed (United Nations, 2025b). To put it differently, education should be the primary strategic investment, not only for individual development but also for determining countries' social welfare.

Education and Skills Directorate of OECD[1] offers data, policy analysis and suggestions on education to guide individuals and countries to develop the skills and knowledge that lead prosperity, create better lives and better jobs (OECD, 2025a). The Directorate publishes Education at a Glance (EAG) report annually to share the information they gathered and presents the countries' status and development based on measurable, globally comparable indicators (OECD, 2025b). On the other hand, EAG report serves as a guide for governments to design more efficient and equal education systems because it is based on official data. Since the governments try to develop policies to improve society's economic and social prospects and create incentives for more enhanced education systems (OECD, 2025b), namely, to achieve Goal 4: Quality Education, they are paying more attention to international comparisons among systems of education; fundamentally, this report is of great importance for them. Moreover, this report is a data source for researchers to analyze theirs or any other country's education system and compare them internationally (OECD, 2025b). Based on this information, the researcher decided to conduct this study in order to understand the difference between two countries' educational systems. In the selection process of the countries for the purposes of current study, previous research about educational systems of different countries and studies related to evaluations of several dimensions of the educational systems (Balcı, 2018a; Balcı, 2018b; Bray et al., 2014; Mutlu, 2016; Mutlu, 2019; Mutlu and Sezgin, 2023), current (OECD, 2025b) and previous OECD reports (OECD, 2022, 2023, 2024), World Bank Group's (2025) data source and Sustainable Development Report written by Sasch et al. (2025) were

[1] OECD (The Organization for Economic Co-operation and Development) is a forum and international source for public policy related data, analysis and practice. They try to create stronger, cleaner and fairer societies by working with one hundred countries worldwide. Their aim is to help countries to offer better policies and better lives (OECD, 2025c).

examined in order to receive some insights concerning the inclusion criteria for the countries to be chosen in the current study. It appeared that previous research studies worked on some global results or theoretical frameworks together with their local and country-wise needs in the determination of the countries to include in their research. As a result of assessments on the above exemplary research, Finland and Türkiye were selected as countries to be analyzed mainly based on the OECD performance indicators and sustainable development progress of the countries.

METHOD

Document analysis was employed as a data collection tool in this qualitative study and the data for the document analysis included the report entitled *"Education at a Glance 2025: OECD Indicators"* (OECD, 2025b) which was published by the OECD Directorate for Education and Skills. This document is published annually, and it includes the analysis of quantitative, internationally comparable indicators that will help governments and researchers to compare countries, which could be further used to promote more effective and equitable education systems around the world (OECD, 2025b). In order to determine which countries should be selected to make comparisons based on several indicators, the researcher of this work, in addition to examining different sources on the subject, decided to employ the results from the global progress report named "Financing Sustainable Development to 2030 and Mid-Century: Sustainable Development Report 2025" published by Sachs and his colleagues (2025) and included countries ranked by their overall score to measure their overall success towards managing all 17 SDGs.

Given the scores of overall performances of UN member states, Finland appeared to be the first among all 193 member countries with its achievement score of 87.02 (Sachs et al., 2025) and it was followed by Sweden and Denmark as the second and third countries among others. Given the local context of the researcher, that is, Türkiye, it was seen that Türkiye became the 73rd among others with a success score of 70.61. These results simply indicted that Finland showed 87% of SDG achievement while Türkiye having almost 71% of achievement score as to the achievement of all of the SDGs in Agenda 30. Thus, the researcher wanted to include Finland as the exemplary country with the highest level of performance on overall achievement in SDGs and Türkiye as her native country and as country with a moderate (or moderate-to-high) degree of overall achievement for the purposes of her further comparative analyses. To summarize, Finland and Türkiye as countries representing two different achievement and progress profiles were compared with one another based on

statistical results from several indicators reported in "Education at a Glance 2025: OECD Indicators" (OECD, 2025b).

The researcher chose some indicators from "Education at a Glance 2025: OECD Indicators" (OECD, 2025b) with an effort to identify the ones that could be associated with one another based on a certain rationale. To put it differently, the researcher wanted to choose some indicators based on a logical and acceptable rationale, which would also act as her units of analyses in the current document analysis study reported here. To serve this general aim, the researcher explored "input-process and outcome" approach based on Systems Theory (Bertalanffy, 1968) by considering the interlinking structures and sub-processes within education being considered as an open system itself. Another piece of theoretical framework for the analyses may also include Biggs'in 3P Model (1999:18) represented with three interlinking units of presage–process and product within educational learning environments and procedures. Stufflebeam's (2000) popular work on program evaluation indicated that evaluation should be employed by paying specific attention to certain sub-components composing the biggest entity. His such opinions led to the development of a model with several sub-categories for further examination and evaluation as "Context–Input–Process–Product" (CIPP).

Guided by the above theoretical frameworks that have particular and critical importance to the understandings of educational institutions and systems, the researcher sought to classify the indicators listed and evaluated in the report, Education at a Glance 2025: OECD Indicators (OECD, 2025b) as input-process and outcome and then identified three variables from each of these three categories for the purposes of this report. The indicator chosen as input was related to government's expenditure on education while process and outcome indicators subsequently included class characteristics (class size and ratios) and educational attainments (qualifications). They were listed in the official report, Education at a Glance 2025: OECD Indicators (OECD, 2025b) as in the following:

i. Key system-level indicators of education finance.
ii. How do student-teacher ratios and class sizes vary across education levels up to upper secondary education?
iii. To what level have adults studied?

Overall, comparisons were performed by the researcher of this paper between Türkiye and Finland according to three main indicators (being treated as units of analyses) as was reported above. There were several figures or tables within the report (OECD, 2025b) related to one particular indicator and the researcher examined all of them prior to listing and coding her keywords or key items for further analyses. Thus, data from the resources were analyzed by means of descriptive analyses of key words and key components (i.e. input-process and outcome) to compare the two countries.

FINDINGS

How much money is spent on educational institutions per student?

In the world, authorities invest on education for numerous reasons, such as enabling equal opportunities and promoting prosperity and economic growth (OECD, 2025b). However, the quantity of investments of the countries differs from one another. Because of tight budgets, governments face some challenges on deciding how much funding should be allocated to education, and how to share these fundings among different education levels (e.g., primary, secondary, tertiary etc.), geographical areas and institution types (OECD, 2025b). When deciding, policy makers consider chancing policy environments along with changes in the demographics and size of the students and teachers' shortages (OECD, 2025b).

In the report it was highlighted that in the calculations of institutional spendings USD is used in order to be a common currency; however, the percentages that allocated from the countries' GDP was also presented because what percentage of a country's GDP was allocated to education is as important as the amount of money that is spent on education. When spending on educational institutions per student was examined, it was understood that OECD countries' governmental expenditure is 12 438 USD, which corresponds to 3% of their GDP, for primary, secondary and post-secondary non-tertiary educational institutions, and 12 750 USD, which corresponds to 1.7% of their GDP, for lower and upper secondary educational institutions on average as presented in Figure 1 and Figure 2. Similar and even larger numbers were presented by Finland authorities. According to the report, for each student in Finland, government spends 13 465 USD, 3.7% of country's GDP, for primary, secondary and post-secondary non-tertiary educational institutions and 14 147 USD, 2.3% of country's GDP, for lower and upper secondary educational institutions. Based on this data, it was understood that on average, Finland spends more money and allocates more share from its GDP than other OECD countries in both educational levels examined. However, when Türkiye's expenditure on educational institutions per student was investigated it was seen that 3 374 USD, 1.8% of country's GDP, is spent for primary, secondary and post-secondary non-tertiary educational institutions and 3 369 USD, 1.2% of country's GDP, is spent for lower and upper secondary educational institutions. This demonstrated that Türkiye is far behind than most of the OECD countries in the context of educational expenditure both in terms of USD spent and GDP allocation. While Finland and Türkiye's expenditures on educational institutions were compared, it was clarified that Finland allots quite a lot of money and a larger share of its GDP than Türkiye. It is a predictable situation that this difference in numbers will have diverse influence on the quality of education.

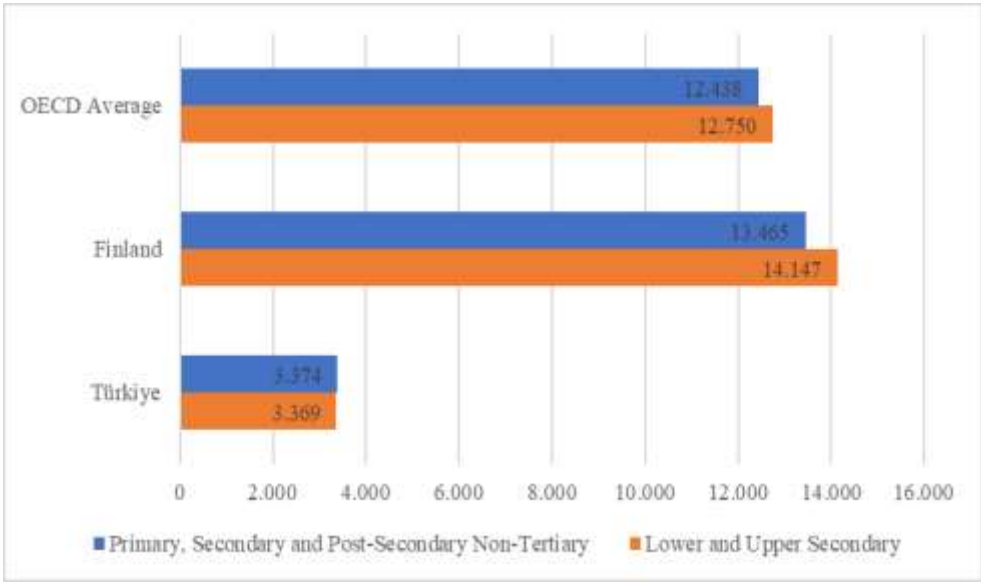

Figure 1: Government Expenditure on Educational Institutions per Student in 2022 (Equivalent in USD)

**Note.* The above information was elicited from Education at a Glance 2025: OECD Indicators (OECD, 2025b, p.286) and the figure was designed accordingly by the researcher.

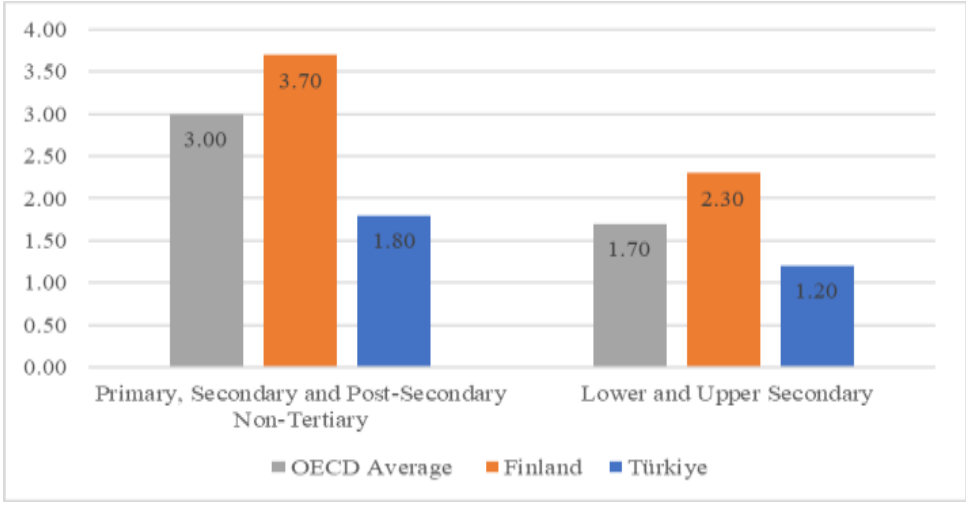

Figure 2. Government Expenditure on Educational Institutions as a Percentage of GDP in 2022

**Note.* The above information was elicited from Education at a Glance 2025: OECD Indicators (OECD, 2025b, p.287) and the figure was designed accordingly by the researcher.

How do class sizes and students-to-teaching-staff ratios change in primary and lower secondary education?

It needs to be highlighted that both class size and students to teacher ratio are important indicators that policy makers monitors since they have a significant influence on educational spending specifically with regard to teacher salaries (OECD, 2025b). These indicators offer significant information about how resources are divided within the system of education and how they can impact academic outcomes (OECD, 2025b). Thus, the other variable that needs to be investigated for this study is how many students are in the classes and how students to teacher ratios changes between Finland and Türkiye. First of all, class sizes should be examined closely. OECD calculated class size by dividing student numbers enrolled into the class numbers. To enable comparability among different countries, programs of special needs were excluded.

When OECD countries' average class size in primary and lower secondary education in public institutions examined, it was understood that 21 students are enrolled per class in primary education and 23 students are enrolled per class in lower secondary education as is shown in Figure 3. When class sizes of Finland institutions were analyzed, it was evident that there are 19 students in classes at both in the primary and lower secondary education levels. Therefore, there is no harm in saying that classes in Finland are more spacious than most of the classes from different OECD countries. However, the numbers from Türkiye presented another scenario. In Türkiye's institutions, there are 22 students in an average class in primary level education and in a lower secondary level education class, there are 28 students. This can be interpreted that even class size in primary level is in a balance with OECD countries, classes from lower secondary level are more crowded than other OECD countries. While class sizes from Finland and Türkiye were compared, it was dedicated that classes of Finland are less crowded than Türkiye's. That is the evidence that a teacher in Finland has to take care of less student through lesson compared to a teacher in Türkiye. Since less students in a class means more attention to each student in the class, education process and quality are directly affected.

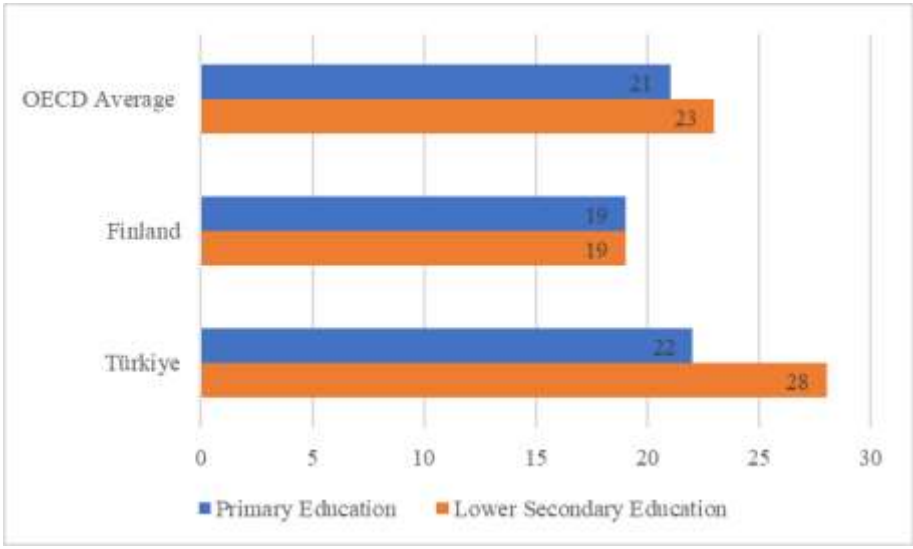

Figure 3: Average Class Sizes in Primary and Lower Secondary Education in 2023

**Note.* The above information was elicited from Education at a Glance 2025: OECD Indicators (OECD, 2025b, p.380) and the figure was designed accordingly by the researcher.

Both in primary and lower secondary education, teachers play a vital role in students' lives (OECD, 2025b) and the interaction between teachers and students has undeniable importance in education. Therefore, in order to understand the quality of education, another significant indicator needs to be investigated, which is students-to-teacher ratios in primary and lower secondary education levels across countries. However, OECD presents data for students to teaching staff ratios. Teaching staff term was used for personnel who are precisely involved in students learning. Under this umbrella term, there are special-education teachers, classroom teachers and other teachers that work with whole students in a class or small groups outside a regular class (OECD, 2025b). In the calculation of this ratio, the number of students at a specific level of education was divided into the teacher numbers at that level. According to the report, the average students to teaching staff ratio in OECD countries is 14 for primary school level and 13 for lower secondary school level, as is shown in Figure 4. As reported by Finland authorities, this number is 12 for primary level and 9 for lower secondary level. This data clarified that a typical teaching staff in Finland whether working in primary or lower secondary school is responsible for less student than her/his colleges in other OECD countries. When Türkiye's data was reviewed, it was seen that the number of students per teaching staff is 18 for primary school level and 13 for lower secondary level. The conclusion to be drawn from this was that even tough in lower secondary level students to

teaching staff ratio is at the OECD average, in primary school level a regular teaching staff in Türkiye has to guide more students than her/his counterparts in other OECD countries. When students to teaching staff ratios from the countries compared, one can comment that both in primary and lower secondary level Finland's teaching staff have an advantage over Türkiye because they have less students under their responsibilities. Thanks to small class sizes, Finnish teachers can allow more time than Turkish teachers for each and every student in their classes and this is another impact factor that affects the quality of the education.

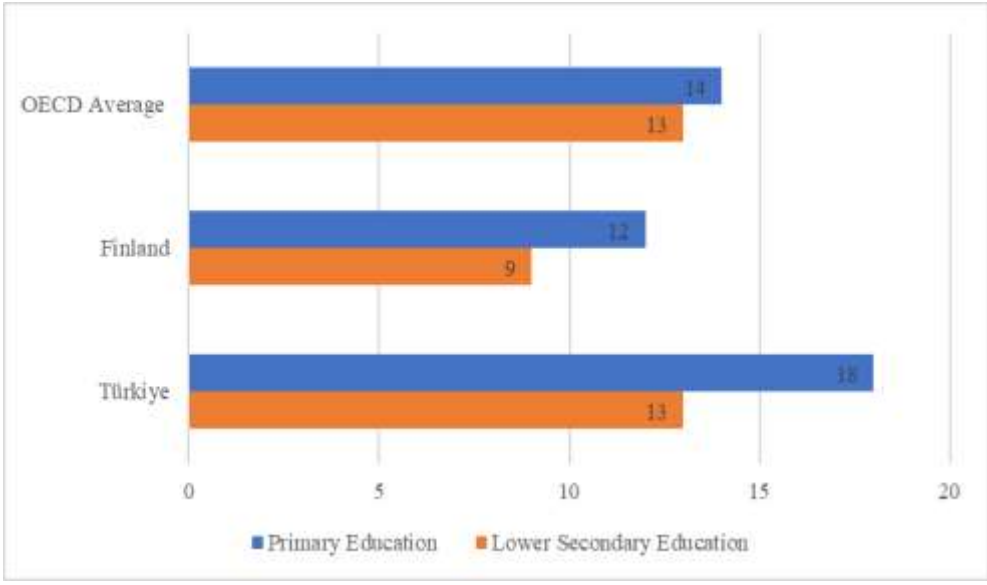

Figure 4: Students to Teaching Staff Ratio in Primary and Lower Secondary Education in 2023

**Note.* The above information was elicited from Education at a Glance 2025: OECD Indicators (OECD, 2025b, p.379) and the figure was designed accordingly by the researcher.

How extensively have adults studied?

Educational attainment has a vital role both in the society and in labor market (OECD, 2025b). Even in the report it is clearly emphasized that higher levels of educational attainment mean more employment rates, more qualified labor force and higher incomes (OECD, 2025b). When it was investigated, it was understood that tertiary education attainment rates of adults have increased across OECD countries over the past years (OECD, 2025b). Moreover, in the report, it was defended that individuals who have tertiary education qualifications usually accomplish higher employment rates and get better rages than people who have lower education level degrees

(OECD, 2025b). Even it was presented in the report that people with master's degree earn more money and confront lower unemployment rates than people who only have bachelor's degree. In the light of these information, educational attainment level of adults in selected countries was investigated as a final indicator to understand how all the investments and the process educated the society. When OECD average was investigated, it was seen that 19% of the people between the ages of 25 to 64 have below upper secondary education degree, 40% of them have upper secondary or post-secondary non-tertiary degree and 42% of them have tertiary education degree as it is presented in Figure 5. In Finland, the rate was 11% for below upper secondary education, 46% upper secondary or post-secondary non-tertiary and 43% for tertiary education levels. It was seen that Finland's adult attainment of below upper secondary education level percentage is lower than OECD average but upper secondary or post-secondary non-tertiary degree and tertiary education levels' percentages nearly the same as OECD average This can be interpreted that on average, an adult living in Finland practically has the same level of education as an adult living in any other OECD country. However, when Türkiye's adult education attainment levels were investigated, the rates changed dramatically. In Türkiye 50% of the population has below upper secondary school degree, which is one of the highest rates for this level of education among OECD countries, 23% has upper secondary or post-secondary non-tertiary degree and lastly 27% has tertiary education degree. These rates showed that an adult who lives in Türkiye has much lower education level than a typical adult living in another OECD country. As it is evident, adults in Finland are much more educated than in adults in Türkiye and they probably live in greater prosperity since higher education levels opens the door for better lives.

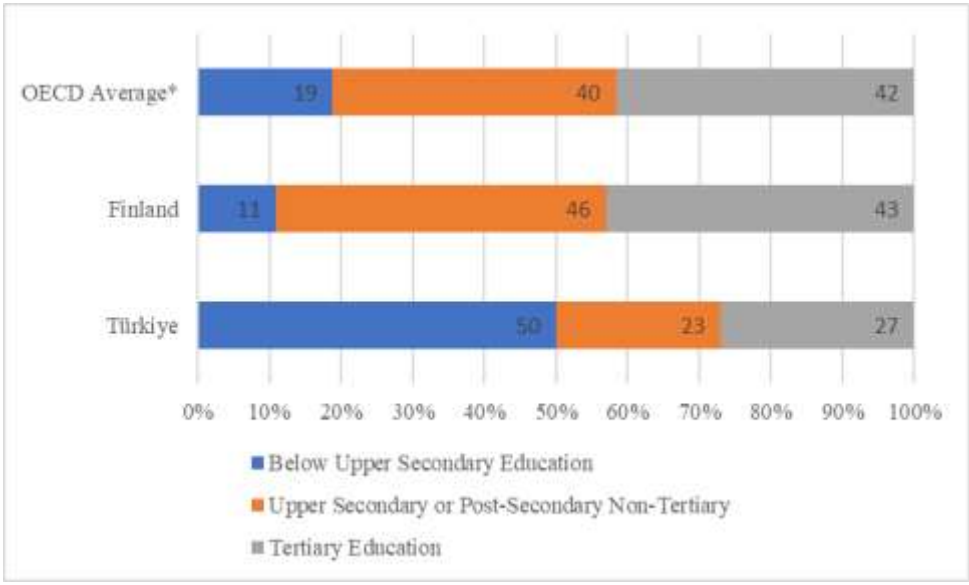

Figure 5: Percentage of 25–64-Year-Olds Educational Attainment

**Note.* Because of the upper rounding system used in the report, OECD average rate for this indicator goes beyond 100 percent in total.
***Note.* The above information was elicited from Education at a Glance 2025: OECD Indicators (OECD, 2025b, p.63) and the figure was designed accordingly by the researcher.

DISCUSSION AND CONCLUSION

As a result of the analyses, it was seen that even though both Finland and Türkiye are classified as OECD countries, their educational profiles present different pictures. To understand the details, firstly government expenditures and GDP allocations for education institutions were investigated in selected countries in question. The results showed that expenditure on educational institutions per student and rate of expenditure as a percentage of GDP in Finland were above the OECD average while Türkiye's amount of educational spending and rate of expenditure as a percentage of GDP were identified in the lower ranks of list of OECD countries. These findings illustrated that for students' education Finland allocated more than twice as many resources as Türkiye. This difference in input can be considered as one of the critical key determents in class characteristics.

Secondly, class sizes and student to teaching staff ratios were compared. According to the data obtained from Education at a Glance 2025: OECD Indicators report (OECD, 2025b), in Finland both class sizes and

students-teacher ratios were below OECD average. Thanks to the higher amounts of budget allocated to education, the classes were spacious and this situation is more likely to help teachers pay more attention to each student in their classes. In Türkiye, although primary school classes had the same number of students in an average OECD country class, lower secondary education classes were more crowded than a typical class in other OECD countries. Moreover, Türkiye's students to teacher ratios were higher than OECD average both in primary education and lower secondary education levels. Thus, it appears that because of tighter budgets, classes happen to be more crowded, and this can hinder teachers from giving sufficiently high amounts of attention to every student in their classes. Based on these data on class size and students to teacher ratios, teachers in Finland naturally appear to have more chance and time to interact with their students individually while teachers in Türkiye appear to manage more students in their classes compared to their colleagues in Finland. This apparently can influence the quality of educational processes.

Lastly, adults' educational attainment levels were analyzed to understand how investments and classroom environment characteristics seemed to result in the form of educational qualifications and attainments by the end of the process. As it was previously mentioned above, educational profiles of adults in Finland were high and most of the adults possessed at least upper secondary or post-secondary non-tertiary education degree. Additionally, in Finland, rates of adults with tertiary degrees were higher than the OECD average. However, in Türkiye, a large part of the adult population had below upper secondary degree, which in fact means that most of the people in the society ended their educational life when the primary education period was completed. These rates can simply show that Finland's system appeared to train students to become qualified experts and university graduates while the system in Türkiye seemed to train most of the people to a level where they generally completed primary education only. The question here is what factors could lead to such results on educational attainments and the researcher of this work wanted to attract attention to the critical influence of financial investments on education and classroom characteristics and conditions upon such attainments.

In summary, it seems clear that Finland invests on education, adjust classes to hold small number of students and keeps student to teacher ratios lower so that every student gets the attention s/he needs. These positive characteristics and conditions encourage students to proceed with their education life towards future levels of attainments and thus support them to continue for tertiary education. However, when resources allocated to education are lower and somehow limited, classes can get more crowded, which seems to make students feel more deprived of teachers' attention. Therefore, it gets more likely for them to end their educational lives by the time they complete their below upper secondary level of education. This

rationale indeed can be valid for most countries with lower educational expenditures compared to Finland including Türkiye. Expenditure on resources for educational institutions can be seen as one of the reasons leading to differences in indicators of quality between the education systems of countries (OECD, 2025b).

With simple logical reasoning, one can simply assume that when individuals live in countries with successful and good quality educational system, they are more likely to continue their educational careers up to tertiary education levels by probably finding opportunities to improve themselves and by believing that they would have a better life by means of gain due to education. In contrast, students living in countries with educational systems that appear to have some malfunctions and limitations are more likely to terminate their educational journeys early by not choosing to attend to tertiary education for their future. These choices of the young generations can automatically affect the structure of society in the long term, and this is not a case solely for the two countries that were compared for the purposes of this study. When people and especially young generation are provided with means to develop their capabilities further by means of education, societies will also develop and get more productive for all people. For that reason, it needs to be highlighted that every investment to reduce the quality gap in education systems helps to create conscious, productive and happy societies in the world and educational systems globally deserve more investments in terms of financial and human resources.

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