INTERNATIONAL ONLINE JOURNAL OF EDUCATIONAL SCIENCES

ISSN:1309-2707

Volume 18 Issue 1 February 2026

iojes

www.iojes.net

International Online Journal of Educational Sciences

IOJES is an international, peer-reviewed scientific journal (ISSN:1309-2707) is published five times annually-in February, June and October.

Volume 18, Issue 1, Year February - 2026

Contact Info.

Address : Yıldız Technical University, Faculty of Education, Department of Educational Sciences Istanbul - Türkiye
Telephone : + 90 542 325 1923
E-Mail : info@iojes.net
Web Site : www.iojes.net

Publication Type: Published in February, June and October.

Indexing
Education Abstract (H. W. Wilson)
Education Full Text (H.W. Wilson)
Turkish Education Index (TEI)
EBSCO host Educational Sources
ERA Routledge
The Asian Education Index
Cite Factor
Index Copernicus

Language editing
Language redactions of the papers are made by professional licensed institutions.

International Online Journal of Educational Sciences

IOJES is an international, peer-reviewed scientific journal (ISSN:1309-2707) is published five times annually-in February, June and October.

Volume 18, Issue 1, Year February - 2026

INDEX

Contact Info.

Address : Yıldız Technical University, Faculty of Education, Department of Educational Sciences Istanbul - Turkey
E-Mail : info@iojes.net
Web Site : www.iojes.net

iojes
www.iojes.net
International Online Journal of Educational Sciences
ISSN: 1309-2707

Distributed Leadership Practices across School Types and Levels: A Mixed-Methods Study

Research Article

Omer Faruk AKGUN[1], Sahin CETIN[2]

[1]Istanbul 29 Mayıs University, Department of Foreign Language Education, Istanbul, Türkiye 0000-0001-6628-5035
[2]Yeditepe University, Department of Foreign Language Education, Istanbul, Türkiye 0000-0003-2757-4584

To cite this article: Akgun, O. F., & Cetin, S. (2026). Distributed leadership practices across school types and levels: A mixed-methods study. *International Online Journal of Educational Sciences*, *18*(1), 1-14.

ARTICLE INFO

Article History:

Received: 13.10.2025

Available online: 03.01.2026

ABSTRACT

The purpose of this study is to examine to what extent leadership is distributed at schools, whether distribution varies depending upon the level and type of the school, what criteria principals use, and what barriers they encounter when distributing leadership. This study employed a mixed-methods design. The quantitative study was based on data collected from 316 teachers using the Distributed Leadership Scale. The qualitative study used data from semi-structured interviews with the principals of the very same schools. Teachers reported that leadership was highly distributed at schools. Distribution was significantly higher at private schools than at public schools; however, no significant difference was found based on school level. Principals expressed a belief in the necessity of distributing leadership mainly for practical reasons. They distributed leadership roles based on expertise and the willingness of teachers, and thought that the reluctance of the stakeholders and legislation in effect posed challenges to distribute leadership. This study offers greater insight into the distribution of leadership across schools with different characteristics, as well as barriers that may undermine its effectiveness.

Keywords:
Distributed school leadership, patterns of distribution, barriers to distributed leadership

Introduction

Traditionally, most of the literature on leadership has focused on the characteristics or behaviors of individual leaders. This perspective is implicitly based on a definition of leadership as influence exerted or direction provided by one individual over others (followers who are usually depicted as recipients or objects of such influence). As organizations have become more complex and their members more interdependent, such views are increasingly regarded as limited in addressing modern challenges. Modern organizations can no longer rely on leadership by one person who is expected to respond to the diverse expectations of various

[1] Corresponding author's address: İstanbul 29 Mayıs University
e-mail: ofakgun@29mayis.edu.tr
DOI: https://doi.org/10.15345/iojes.2026.01.001

stakeholders (Corrigan, 2013). Confining leadership practice to individuals in formal leadership roles is not realistic, either (Harris & Spillane, 2008).

Formal leaders inevitably carry out their role behaviors through and within interactions with a number of individuals, some of whom may also assume leadership responsibilities. For example, research has shown that leadership activities are typically carried out by three to seven positional leaders in U.S. schools (Camburn, Rowan, & Taylor, 2003). In one U.S. school district, principals reported that they co-performed 47% of their administrative and instructional duties with at least one other person, and 37% of the time that other person was a classroom teacher without a formal leadership role (Spillane, Camburn, & Pareja, 2007).

In response to such criticism, scholars have increasingly emphasized newer forms of leadership, specifically distributed leadership. Far from being a simple synonym for delegation, distributed leadership refers to leadership by multiple individuals whose combined expertise enables them to work in coordination toward shared goals. Multiple contributions are made coherent through common goals and a shared culture of improvement (Elmore, 2000; Gronn, 2002; Spillane, 2006). For such productive and synergistic interactions, organizations need systems that bring and hold multiple leaders together (Harris, 2004). Such leadership is a fluid and emergent group phenomenon rather than a fixed entity based on formal role or hierarchy (Spillane, 2006). It emerges from interactions between multiple leaders with informal as well as formal roles (Bennett, Wise, Woods, & Harvey, 2003; Copland, 2003).

Importantly, distributed leadership does not remove responsibility from formal leaders. It does not imply that there is no one with overall responsibility for the organization's well-being (Elmore, 2000) or that everyone leads simultaneously. Well-planned orchestration and coordination of multiple leaders' contributions are critical for organizational success (Harris, 2008).

To understand how this distribution occurs, the literature offers several converging taxonomies that move beyond simple ad-hoc collaboration. Emphasizing the additive aspect of distributed leadership, Gronn (2002) introduced the notion of concertive action to describe members of an organization pooling their expertise to solve problems. This manifests in three forms: spontaneous collaboration, intuitive working relations, and institutionalized practices. Spontaneous collaboration emerges when individuals work together in an unplanned and unassigned way to solve a problem. Intuitive working relations develop out of trust among individuals who agree on courses of action regarding organizational issues. Institutionalized practices, such as formal subject groups, committees, and boards at schools (Kurt, 2016) are formal and structural (Gronn, 2002). Expanding on this, Spillane (2006) distinguished between collaborated distribution (two leaders working together simultaneously), collective distribution (leaders working separately but interdependently), and coordinated distribution (sequential leadership tasks).

Further nuanced by MacBeath, Oduro & Waterhouse (2004) and Leithwood et al. (2007), these forms range from planful alignment—where distribution is strategically orchestrated—to spontaneous misalignment or anarchy, where uncoordinated leadership pulls the school in opposing directions. This theoretical synthesis suggests that distributed leadership is not inherently effective; its success depends on the coherence of these distributed actions (Harris et al., 2007).

Empirical evidence indicates that distributing leadership offers important benefits; however, to realize these benefits, organizations must carefully plan what is to be distributed, why, and how. Distributed leadership has been found to correlate positively with various school- and teacher-related variables, including school goal achievement, instructional program management (Obadara, 2013), school performance (Davis, 2009; Harris & Muijs, 2004), and professional learning communities (Louis & Marks, 1998). Furthermore, it is associated with enhanced teacher self-efficacy, morale, and enthusiasm (Sheppard et al., 2010), as well as increased organizational trust (Adıgüzelli, 2016) and commitment (Hulpia et al., 2010).

Yet, there is also considerable evidence warranting skepticism. Research suggests that leadership distribution can lead to conflicting priorities and competing leadership styles (Storey, 2004; Timperley, 2005). Critics argue that much of distributed leadership may be "dressed-up delegation" (Lumby, 2013), and principals often remain reluctant to share genuine power due to accountability pressures or a lack of trust in teacher capacity (Börü, 2020).

Furthermore, engaging multiple actors in leadership is challenging, especially when these actors are not prepared to assume leadership responsibilities. Research has shown that teachers are sometimes reluctant to participate in administrative processes (e.g., Lizotte, 2013; Smith, 2007; Tahir et al., 2016). Other factors may also hinder distributed leadership. In Turkey, Börü (2020) found that principals were reluctant to share leadership with teachers or parents. They perceived teachers as unwilling or unqualified to assume leadership and feared that distribution could foster competition and jealousy. Similarly, principals avoided sharing leadership with parents, fearing unfair demands and pressure on teachers. They believed that leadership by a single individual was more effective—a view reinforced by existing legislation (Börü, 2020).

Overall, there is compelling evidence that distributed leadership offers substantial benefits, but these do not occur automatically. Various factors, specifically the organizational structure (level) and the institutional culture (type), facilitate or hinder its practice. Therefore, this study aims to provide deeper insight into how leadership distribution varies across these specific contexts, responding to the call for research that moves beyond if distributed leadership works, to how it works in different organizational ecologies.

Specifically, the purpose of this study was to examine the level of distributed leadership perceived by teachers in public and private schools in İzmir, Turkey. Specifically, we sought to answer the following research questions:

- Do teachers' perceptions of distributed leadership vary significantly according to school level (elementary, middle, or high) and type (public or private)?
- What are the barriers that undermine distributed leadership in schools?
- What criteria do principals use to distribute leadership tasks and responsibilities?

While the benefits and challenges of distributed leadership are well-documented, the literature often treats schools as monolithic organizations, neglecting the structural and cultural distinctiveness of different school types. This study addresses that gap by explicitly comparing distributed leadership across school levels (primary vs. secondary) and school types (public vs. private).

The necessity of investigating distributed leadership across grade levels stems from the fundamental differences in organizational complexity and coupling. According to Weick's (1976) theory of educational organizations as "loosely coupled systems," secondary schools exhibit significantly looser coupling than primary schools. Secondary schools are often characterized by distinct subject departments ("silos") and a "balkanized" culture (Hargreaves, 1994), where teachers identify more with their subject matter than the school as a whole. This structural fragmentation makes the coordination aspect of distributed leadership more difficult but also more critical. In contrast, primary schools typically feature a smaller span of control and a more holistic, child-centered culture, potentially facilitating more spontaneous and collaborative forms of distribution (Spillane, 2006). Therefore, treating primary and secondary school leadership as identical overlooks the structural "glue" required to hold these different systems together.

Similarly, comparing public and private schools offers a critical theoretical lens grounded in Institutional Theory and Resource Dependence Theory. Public and private schools operate under fundamentally different accountability regimes which shape their internal leadership dynamics (Benveniste, Carnoy & Rothstein, 2003). Public schools are typically subject to "bureaucratic accountability"—a top-down system driven by state mandates and compliance with external regulations (O'Day, 2002). This bureaucratic layering often rigidifies the hierarchy, potentially inhibiting the flexibility required for genuine distributed leadership; principals may function more as "middle managers" enforcing external policy rather than architects of internal distribution (Goldring & Schuermann, 2009).

In contrast, private schools primarily face "market accountability", where they are accountable to parents and clients rather than state bureaucracies (Lubienski, 2003). This market orientation often necessitates a strong focus on "customer orientation" and responsiveness, which can drive schools to adopt flatter, more collaborative leadership structures to ensure high-quality service delivery and client satisfaction (Oplatka, 2007). Furthermore, private school principals typically enjoy greater organizational autonomy in hiring, curriculum design, and resource allocation compared to their public counterparts (Chubb & Moe, 1990). This autonomy theoretically allows private school leaders to distribute leadership more authentically based on expertise rather than formal role, whereas public school distribution may be constrained by state mandates. Investigating these differences is vital for understanding how the source of accountability (state vs. market) influences the practice of leadership distribution.

Method

Research Design

This study adopted an explanatory sequential mixed-methods design and included both quantitative and qualitative components (Creswell & Plano Clark, 2011). As a research approach that combines these two methodologies within a single study, it aims to provide a more comprehensive understanding of the phenomenon that is investigated (Glogowska, 2011).

In the first phase of the study, quantitative data were collected from teachers to examine the extent to which leadership was perceived as distributed and to identify any potential differences in these perceptions across school types and levels. In the second phase, qualitative data were gathered through semi-structured interviews with principals working in the same schools. The purpose of the qualitative phase was to provide explanatory depth to the quantitative findings by exploring how leadership was actually distributed in daily practice, which factors facilitated or hindered distribution, and what criteria principals used when allocating leadership responsibilities.

Participants

Participants of the quantitative study comprised 316 teachers working at public and private schools in Izmir, Turkey. According to the official website of Izmir Directorate of Education, the total number of schools in the province where the study took place was 80, and the total number of teachers was 2364. In order to ensure maximum variation in terms of school characteristics, schools were first classified according to grade level as elementary (26 schools), middle (32 schools), and high schools (22 general education track high schools). Next, schools in each grade level were grouped according to school type as public or private. There were 13 public and 13 private elementary schools, 14 public and 18 private middle schools, and 6 public and 16 private high schools. Finally, two public and two private schools from each grade level were randomly selected. Thus, the 12-school sample consisted of four elementary schools (two public and two private), four middle schools (two public and two private), and four high schools (two public and two private). A total of 380 teachers and 12 principals worked at these schools, and 316 of them participated in the study. As regards grade level, 115 teachers (36.4% of the sample) worked at elementary schools (56 teachers at public and 59 teachers at private elementary schools), 100 teachers (31.6% of the sample) worked at middle schools (51 teachers at public and 49 teachers at private middle schools), and 101 teachers (32% of the sample) worked at high schools (45 teachers at public and 56 teachers at private high schools). Demographic characteristics of participants can be seen in Table 1.

Table 1. Demographic characteristics of participants

Category	Criterion	N	%
Gender	Female	232	73.4
	Male	84	26.6
Age	23-43	230	72.8
	44-64	86	27.2
School Type	Public	152	48.1
	Private	164	51.9
Subject	English	60	19.0
	Social Studies	23	7.3
	Maths	32	10.1
	Turkish	33	10.4
	Science	37	11.7
	Elementary (K4)	74	23.4
	Psychological Counselor	16	5.06
	Arts	19	5.99
	Other*	22	6.94
Total		**316**	**100**

* (Physical Ed.: 10, Theology: 9; ICT: 3)

As shown in Table 1, the majority of participants were female (232 participants, 73.4% of the sample) and aged between 23 and 43 years (230 participants, 72.8% of the sample). Regarding school type, slightly more than half of the participants worked at private schools (164 participants, 51.9% of the sample). In terms of school subject taught, 74 participants (23.4% of the sample) were elementary (K4) school teachers, and 60 participants (19% of the sample) were teachers of English.

The qualitative study was based on semi-structured interviews with the principals of the 12 schools in the sample. After specifying the sample of the quantitative study, we visited each principal personally and informed him/her about the study. Next, explaining the objectives and questions of the qualitative study, we asked the principal whether he/she would personally agree to participate in the qualitative study, to which all principals but one agreed. An appointment was set for the interview. Consequently, the participants of the qualitative study comprised 11 principals. Three participants were elementary school principals (two public, one private), four participants were middle school principals (two public and two private middle schools), and four participants were high school principals (two public and two private high schools). Eight (8) participants were male, and three were female; their tenure as principals varied between one year and 23 years.

Data Collection Tools and Procedure

We visited the schools in the sample in 2017 - 2018 to administer the questionnaire forms. We distributed and collected back 326 forms but had to revoke 10 forms due to missing or faulty information. SPSS 25 was used to analyze quantitative data. Forms involved questions on teachers' demographic characteristics (age, gender, subject area, tenure, and school type and level) as well as the Distributed Leadership Scale. The Distributed Leadership Scale, which was adapted from Davis (2009) into Turkish by Özer and Beycioğlu (2013), is a 5-point Likert-type scale with 10 items and one factor. Using items like "The principal tries to create a climate based on sharing," and "Teachers at this school are willing to participate in administrative processes," the scale asks teachers to specify the extent to which each item describes the institution or the principal. The maximum score is 50 points, and the higher the score, the more positive the respondent is about the distributed leadership practice at their institution. Özer and Beycioğlu (2013) found a (.92) Cronbach's alpha value for internal consistency and a (.82) value for test-retest correlation. Cronbach's alpha value for the current study was found to be (.88).

Although the scale had previously been validated for the Turkish context by the researchers who developed it, a pilot study (N=103) was conducted to confirm its construct validity for this specific sample. A Confirmatory Factor Analysis (CFA) using Principal Component Analysis was performed. The data showed excellent sampling adequacy with a KMO value of .899 and a significant Bartlett's Test ($X2(45) = 808.47$, $p < .001$). Results confirmed a strong single-factor structure with an initial eigenvalue of 6.35, accounting for 63.48% of the total variance. Factor loadings for all 10 items were high, which ranged from .68 to .89. Combined with a Cronbach's alpha of .88 for the main study (N=316), these results show that the Distributed Leadership Scale is a highly valid and reliable instrument for this population also corroborating the original findings of Özer and Beycioğlu (2013).

The qualitative study was based on semi-structured interviews with the principals of the same schools. Interview questions focused on principals' views on distributed leadership in general and specifically at their schools. In order to develop interview questions, the related literature was thoroughly reviewed, and 7 questions were prepared initially. Next, the initial list of questions was emailed to three scholars whose research interests involved distributed leadership. Explaining the purpose and the method of the study, scholars were asked to review the questions and suggest corrections or add/remove/reword items as they deemed necessary. Using feedback from scholars, three more questions were added to the initial list of items, hence a qualitative data collection tool consisting of 10 open-ended items.

Interviews with principals were carried out in June 2017 in their offices. Interviews took about 30 minutes each on average and were later transcribed by one of the researchers. Right after each interview, the transcripts were read and verified by researchers together, and changes were made if necessary. At this point, using letters as substitutes for names, each interview was coded like Principal Mr. A., Principal Mrs. B., etc.

Data Analysis

The quantitative data were analyzed using IBM SPSS Statistics (Version 25). Prior to conducting comparative analyses, the data were screened to ensure they met the assumptions required for parametric testing. Specifically, descriptive statistics including the mean, standard deviation, skewness, and kurtosis were calculated to examine the data distribution and evaluate its normality.

Table 2. Normality Test Results for the Distributed Leadership Scale (DLS)

Dimension	Mean	S.D.	Skewness	Kurtosis
Distributed Leadership Perception	4.59	0.49	-1.174	0.475

As shown in Table 2, the skewness and kurtosis values for teachers' perceptions of distributed leadership were -1.174 and 0.475, respectively. Tabachnick and Fidell (2013) suggest that a distribution is considered normal when skewness and kurtosis fall within ±1.5. Given that the observed values fall within these thresholds, the data were treated as normally distributed, thereby justifying the use of parametric procedures, including independent samples T-tests and One-way ANOVA, to address the research questions.

Regarding the qualitative data, after all interviews were completed, thematic analysis was employed to analyze the data. First, each transcript was read twice by each researcher independently, and descriptive notes were written in the margins. There were no predetermined categories for analysis, but themes were extracted inductively from the texts. After individual analyses were completed, researchers came together and compared the themes extracted from the data. In this phase, a reiterative process was followed, and by reading excerpts from the transcripts over and over, researchers sought to reach a consensus on themes.

Findings

Quantitative Study

This study aimed to examine the practice of distributed leadership as perceived by teachers at public and private schools in Izmir, Turkey. Descriptive analyses were run to find mean and standard deviation for the Distributed Leadership Scale. Results are presented in Table 3.

Table 3. Descriptive statistics for the Distributed Leadership Scale

Scale	Items	$\bar{X}$	S.D
DLS	1	4.59	.613
	2	4.74	.487
	3	4.55	.663
	4	4.53	.678
	5	4.59	.629
	6	4.67	.556
	7	4.36	.811
	8	4.60	.647
	9	4.58	.674
	10	4.68	.588
	Scale Total	**4.59**	

As seen in Table 3, the items with the highest mean scores are item # 2 (The principal at this school supports teachers' efforts to improve teaching and learning) (M = 4.74) and item # 10 (Teachers, students, and parents can express their ideas and concerns to the principal openly) (M = 4.68), respectively. The items with the lowest mean scores are item 7 (M = 4.36) and item 4 (M = 4.53). Scale mean is high (M = 4.59), implying that teachers believe leadership at schools is highly distributed.

Next, we conducted an independent samples t-test and One-Way ANOVA to find out whether teachers' perceptions of distributed leadership varied significantly according to the type (public or private) and level (elementary, middle, or high school) of the school. Findings are presented in Table 4.

Table 4. Teachers' Perceptions of Distributed Leadership by School Characteristics

Scale	School Type	N	$\bar{X}$	S.D.	T	P
Distributed Leadership Scale	Private	164	4.79	.29	8.44	.000
	Public	152	4.37	.55		
	Level					
	Elementary	106	4.50	.52	2.92	.056
	Middle	100	4.64	.46		
	High	110	4.63	.45		

As shown in Table 3, teachers' perceptions of distributed leadership varied significantly ($p<0.05$) according to the type of the school. In other words, participants believed that leadership was significantly more distributed in private schools than in public schools. However, there was no significant difference ($p=0.056$; $p>0.05$) between teachers' perceptions according to the grade level of the schools. Nevertheless, it is important to note that *the p-value* is very close to the cut-off point.

Qualitative Study

The qualitative part of this study aimed to delve deeper into the practice of distributed leadership at schools. We specifically focused on the criteria that principals use to distribute leadership and the barriers they encounter throughout this process. Findings of the qualitative study generally support findings of the quantitative study.

Distribution: A necessity for practical reasons. The first question asked during interviews focused on principals' opinions about distributing leadership responsibilities. All principals expressed a strong positive attitude toward distributed leadership and described school leadership by one person as *unthinkable* and *outdated*. They stated that three factors accounted for *the need to distribute leadership: practical necessities, expertise,* and *potential benefits.* In terms of *practical necessities, time constraints* and *administrative workload* were the most frequently cited factors. Principals have too many responsibilities, and they have to deal with many different –and often urgent- problems. *With so much to do, time is hardly enough, and even if a principal can find time to deal with all these problems, (s)he does not have the necessary expertise.* (Principal Mr. E). *A principal who does not delegate will somehow have to admit his/her inadequacy* (Principal Mr. F). And *for sound administrative decisions, it is necessary to utilize everyone's intelligence and expertise* (Principal Mrs. B). Principals listed two major *potential benefits* of distributed leadership: *decision acceptance* and *improving organizational culture*. Participants stated that top-down decision-making undermined teachers' commitment to decisions, and therefore, *participating and assuming responsibility in decision processes helped improve commitment to decisions* (Principal Mr. A). *When teachers are involved in important decisions, they feel happier and more valued, and this promotes a more positive and co-operative climate* (Principal Mr. H).

Barriers to Distributed Leadership. The second research question of this study focused on principals' views about the factors hindering leadership distribution. Three major themes emerged from the analysis of data. The first theme was termed "*stakeholders' attitudes*." Participants claimed that especially teachers' and parents' attitudes were major factors rendering distributed leadership difficult. The most important teacher-related factor was unwillingness to assume responsibility, and it was associated to variables like teacher job dissatisfaction and professional exhaustion. For example, one school principal (Principal Mr. A.) argued that *teachers did not want to take responsibility because, being underpaid, they've lost much of their motivation to contribute extra time and effort to various school processes.* Regarding parents, loss of faith in the value of education or indifference toward educational responsibilities as parents were believed to stifle distributed leadership. Some participants argued that parents' unwillingness was also related with socioeconomic status and students' grade level. Parents with lower socioeconomic status (e.g., *blue collar workers* – Principal Mr. I) did not seem to care much about their children's schooling. Participants stated that parental involvement decreased, especially at the high school level, where many parents did not even want to participate in meetings at school held twice a year. Along similar lines, some parents' enthusiasm to *over-participate,* which sometimes bordered on intervention into the inner workings of the school, also undermined distributed leadership.

The second theme that emerged from the analysis of interview data was termed *"legislation."* Participants claimed that rules, regulations, and written procedures gave principals little leeway and flexibility but too much responsibility, especially in the case of a major problem. Principals were assigned responsibility for anything and everything that took place within the school, and this huge burden discouraged them from delegating or sharing responsibilities. *… formal rules and regulations are major barriers... It is the principal who has to sign his/her name on any document regarding the school… and it is only the principal, and no one else that is bound by such legislation.* (Principal Mr. K.) Although such practices as participation and shared responsibility are legally sanctioned, they do not translate into reality. *Truth be told, sometimes regulations suggest distribution of responsibilities, but that is just in word… practically principals continue to be the main actors with responsibility.* Principal Mr. J.

The third theme extracted from the analysis of data was "*time constraints*." Especially at private schools, teachers were assigned high levels of teaching loads, and combined with related responsibilities, this burden kept most teachers very busy. Teachers' working hours were almost fully consumed by teaching, and such related activities as planning, assessment and coordination. This workload made the distribution of leadership ineffective and unproductive at best.

Criteria Used for Distribution: Expertise and Willingness. The third research question focused on the criteria principals used in distributing leadership responsibilities at school. Two themes emerged from analysis of data: "*expertise*" and "*willingness*." Six participants claimed that they distributed leadership based on teachers' expertise, and interests and they believed such distribution had a positive impact on the overall effectiveness of the school. Distribution based on expertise was thought to be a necessity because principals are former teachers with expertise in their respective subject areas and some experience in administration. Thus, most projects and processes render necessary participation of a number of individuals with expertise in various areas. Distribution based on expertise was easier at larger schools, because these schools had a more *diverse teacher population and a richer pool of talents and interests*. (Principal Mr. K.) Some participants stated that *personality traits (esp. conscientiousness* (Principal Mrs. C.), *loyalty, commitment, and identification* (Principal Mr. D), *interests and skills/competence had to be taken into account as well, and such distribution was ultimately akin to finding the right person for the right job."* (Principal Mrs. C.). *Certification* (Principal Mr. J.) *and postgraduate degree* (Principal Mr. D.) were commonly used by principals in judgment of a teacher's expertise.

The second criterion principals used in decisions of distribution was found to be "*willingness.*" Willingness of teachers to assume leadership roles was believed to be *more important than tenure and experience* (Principal Mrs. G.) Principals reiterated instances where *young and inexperienced teachers with high levels of motivation* volunteered for some major projects and won success (Principal Mr. H.). *Teachers with leadership potential* were usual candidates in such situations (Principal Mr. I.). One principal thought that such skills as *classroom management* were *important clues for the potential of the teacher* and that *such teachers should be talked into assuming responsibility in administrative duties* (Principal Mr. E.).

Discussion

This study aimed to find out if leadership distribution varied according to the grade level and type (public vs. private) of the school. Criteria used and barriers encountered by principals in distributing leadership responsibilities were also investigated.

Teachers participating in the study believe that distributed leadership is prevalent at schools. Findings of the qualitative study indicate an alignment between teachers' and principals' attitudes toward distributed leadership. Principals working at different types and levels of schools consistently and unanimously believe that leadership by a single individual is no longer viable. Participants' remarks on distributed leadership seem to converge on two main points: school leadership by one individual is unthinkable and outdated, and distributed leadership helps improve decision quality at schools. Practical necessities (e.g., time constraints), expertise, and potential benefits render distributed leadership necessary. The second important aspect of distributed leadership emphasized by participants is its positive influence on decision quality and implementation.

The second major finding of this study is that leadership distribution varies depending upon certain characteristics of schools. For example, a significantly higher level of distributed leadership was found at private schools than at public schools. We believe that this is mainly related to the culture of accountability at private schools, where key decisions like hiring/firing are based on performance appraisals. A teacher or a principal with a negative performance evaluation might face the risk of losing his/her job at the end of the school year. The qualitative data support this quantitative trend; two private school principals explicitly noted that teachers' active involvement in administrative tasks is driven, in part, by end-of-year performance evaluations, as teachers strive for high ratings to ensure job security. Consequently, most private schools integrate teacher involvement and participation into their teacher performance evaluation schemes, thereby encouraging teachers to assume greater responsibility in school processes. In contrast, teachers/principals at public schools are often protected from such performance-linked pressures by legislation, and the culture of accountability is less stringent.

The quantitative findings show that teachers' perceptions of distributed leadership do not vary significantly across school levels. Theoretically, with one teacher in charge teaching all the subjects in one class, elementary schools might have a more limited pool of expertise than middle and high schools. In contrast, middle schools and high schools have many teachers with expertise across a variety of diverse subjects, which can facilitate the distribution of various leadership functions or issues. However, the findings of our study showed that these structural differences did not lead to significant differences in distributed leadership within this sample. While the current results indicate homogeneity across levels, the proximity of the p-value to the significance threshold ($p = .056$) suggests that future research with larger, more diverse sample sizes would be beneficial to determine if specific contextual trends exist that were not captured in the current study.

The third major finding of this study regards factors hindering distributed leadership. Three factors were found to undermine distributed leadership: stakeholders' (especially teachers' and parents') attitudes, legislation, and time constraints. Teachers' and parents' unwillingness to assume leadership roles and responsibilities stands out as the most important challenge stifling distributed leadership. This finding is further corroborated by the findings of the quantitative study. Based on teachers' views, the item with the lowest mean score was item 7 (Teachers are willing to make contributions to the administrative processes at school). Teachers' unwillingness to participate in administrative processes at school was also documented in similar other studies as well (e.g., Lizotte, 2013; Smith, 2007; Tahir et.al., 2016; Yılmaz & Turan, 2015).

The negative impact of the bureaucratic accountability system, which assigns all responsibility to principals, also complicates distributing leadership responsibilities. Such structural problems are more severe at public schools and cause these principals to adopt leadership styles that are more one-leader and control-oriented. Distributed leadership seems to be seriously hampered if it is not supported and facilitated by structural and legal arrangements.

The fourth major finding of the study regards the criteria employed by principals in distributing leadership responsibilities. Two considerations were found to be critical: expertise and willingness. Schools are knowledge-intensive organizations consisting of individuals with a wide array of expertise. As such, this finding aligns with the very definition of distributed leadership as well as empirical evidence (e.g., Smith, 2007), which shows that expert and experienced teachers are more likely to take up leadership roles.

Conclusions

This study has important practical implications. Distributing leadership at schools where strong organizational cultures may have developed over the years is not easy. Unwillingness of teachers and parents to assume leadership is an important issue that principals have to deal with in the first place. When some critical and burdensome leadership functions are distributed to individuals who do not want to take extra responsibility, organizational effectiveness is seriously undermined. Furthermore, as shown by Börü (2020), even if teachers and parents are willing to assume leadership, principals might be reluctant to share leadership for various reasons. Schools are organizations where leadership by a single individual in charge has been the norm. It is beyond discussion that stretching leadership over individuals with knowledge and expertise can benefit schools substantially, yet encouraging and coordinating leadership by multiple individuals is a daunting challenge. Without structural arrangements and accompanying cultural change to facilitate it, distributed leadership might do more harm than good. Institutionalizing certain practices where multiple leadership roles are carefully defined and boundaries demarcated can be a key step towards facilitating distributed leadership.

Finally, this study has certain limitations as well. The qualitative study focused on the criteria used in making leadership distribution decisions and the barriers to distributed leadership. For a deeper and better understanding of distributed leadership at schools, further research is needed regarding what leadership functions (or roles) are distributed, on what grounds principals do or don’t distribute certain leadership functions, what teachers who assume leadership roles experience in dealing with the challenge, and what positive or negative outcomes arise as a result of leadership distribution.

Acknowledgements: This study is based on the Master of Education thesis written by the first author and advised by the second author, which was completed in 2019.

REFERENCES

Adıgüzelli, Y. (2016). Dağıtılmış liderlik ile örgütsel güven arasındaki ilişkinin öğretmen görüşlerine göre incelenmesi. *Eğitim ve Bilim*, *41*(185), 269-280.

Bennet, N., Wise, C., Woods, P. A., & Harvey, J. A. (2003). *Distributed leadership.* National College of School Leadership.

Benveniste, L., Carnoy, M., & Rothstein, R. (2003). *All else equal: Are public and private schools different?* Routledge.

Börü, N. (2020). Organizational and environmental contexts affecting school principals' distributed leadership practices. *International Journal of Educational Leadership and Management*. doi: 10.17583/ijelm.2020.4482

Camburn, E., Rowan, B., & Taylor, J. (2003). Distributed leadership in schools: the case of elementary schools adopting comprehensive school reform models. *Educational Evaluation and Policy Analysis*, *25*(4), 347-373.

Chubb, J. E., & Moe, T. M. (1990). *Politics, markets, and America's schools*. Brookings Institution Press.

Copland, M. A. (2003). Leadership of inquiry: building and sustaining capacity for school improvement. *Educational Evaluation and Policy Analysis, 24*(4), 375-395.

Corrigan, J. (2013). Distributed leadership: rhetoric or reality? *Journal of Higher Education Policy and Management*, *35*(1), 66-71.

Creswell, J. W. & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research.* Sage.

Davis, M. W. (2009). *Distributed leadership and school performance* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Thesis database. (UMI No. 3344534)

Day, C. et al. (2009). *The impact of school leadership on pupil outcomes: Final report*. Department for Children, Schools and Families.

Elmore, R. (2000). *Building a new structure for school leadership*. The Albert Shanker Institute,

Ereş, F. & Akyürek, M. İ. (2016). İlkokul müdürlerinin dağıtılmış liderlik davranışları ile öğretmenlerin iş doyumu algıları arasındaki ilişki düzeyleri. *Gazi Eğitim Fakültesi Dergisi*, *36*(3), 427-449.

Glogowska, M. (2011). Paradigms, pragmatism and possibilities: mixed-methods research in speech and language therapy. *International Journal of Language & Communication Disorders*, *46*(3), 251–260.

Goldring, E., & Schuermann, P. (2009). The Changing Context of K–12Education Administration: Consequences for Ed.D. Program Design and Delivery. *Peabody Journal of Education*, 84(1), 9-43.

Gronn, P. (2000). Distributed properties: a new architecture for leadership. *Educational Management Administration & Leadership*, *28*(3), 317-338.

Gronn, P. (2002). Distributed leadership as a unit of analysis. *The Leadership Quarterly*, *13*(4), 423-451.

Hargreaves, A. (1994). *Changing teachers, changing times: Teachers' work and culture in the postmodern age*. Teachers College Press.

Harris, A. & Muijs, D. (2004). *Improving schools through teacher leadership.* Oxford University Press.

Harris, A. & Spillane, J. (2008). Distributed leadership through the looking glass. *Management in Education*, *22*(1), 31-34.

Harris, A. (2004). Distributed leadership and school improvement: leading or misleading? *Educational Management Administration and Leadership*, *32*(1), 11-24.

Harris, A. (2007). Distributed leadership: conceptual confusion and empirical reticence. *International Journal of Leadership in Education*, *10*(3), 1-11.

Harris, A. (2008). Distributed leadership: according to the evidence. *Journal of Educational Administration*, *46*(2), 172 - 188.

Harris, A., Leithwood, K., Day, C., Sammons, P., & Hopkins, D. (2007). Distributed leadership and organizational change: reviewing the evidence. *Journal of Educational Change*, *8*, 337-347.

Hulpia, H. & Devos, G. (2009). Exploring the link between distributed leadership and job satisfaction of school leaders. *Educational Studies*, *35*(2), 153–171.

Hulpia, H., Devos, K., & Van Keer, H. (2010). The influence of distributed leadership on teachers' organizational commitment: A multilevel approach. *The Journal of Educational Research, 103*, 40-52.

Kılınç, A. Ç. (2014). A quantitative study of the relationship between distributed leadership and organizational citizenship behavior: Perceptions of Turkish primary school teachers. *Journal of Curriculum and Teaching, 3*(2), 69-78.

Kurt, T. (2016). Öğretmen liderliğini açıklamaya yönelik bir model: dağıtımcı liderlik, örgütsel öğrenme ve öğretmenlerin öz yeterlik algısının öğretmen liderliğine etkisi. *Eğitim ve Bilim*, *41*(183), 1-28.

Leithwood, K. & Jantzi, D. (2000). The effects of transformational leadership on organizational conditions and student engagement with school. *Journal of Educational Administration*, *38*(2), 112-129.

Leithwood, K., Day, C., Sammons, P., Harris, A., & Hopkins, D. (2007). *Leadership and student learning outcomes: Interim report.* DCSF.

Lizotte, J. O. (2013). *A qualitative analysis of distributed leadership and teacher perspective of principal leadership effectiveness.* (Doctor of education thesis, Northeastern University, Boston, MA).

Louis, K. S. & Marks, H. (1998). Does professional community affect the classroom? Teachers' work and student work in restructuring schools. *American Educational Research Journal*, *33*(4), 757-798.

Lumby, J. (2013). Distributed leadership: The uses and abuses of power. *Educational Management Administration & Leadership*, 41(5), 581-597.

MacBeath J., Oduro, G. K. T., & Waterhouse, J. (2004). *Distributed leadership in action: a study of current practice in schools*. National College for School Leadership.

Mascall, B., Leithwood, K., Straus, T., & Sacks, R. (2008). The relationship between distributed leadership and teachers' academic optimism. *Journal of Educational Administration*, *46*(2), 214-228.

Mayrowetz, D. (2008). Making sense of distributed leadership: exploring the multiple usages of the concept in the field. *Educational Administration Quarterly, 44*(3), 424-435.

Morrissey, M. S. (2000). *Professional learning communities: An ongoing exploration.* Southwest Educational Development Laboratory.

Obadara, O. E. (2013). Relationship between distributed leadership and sustainable school improvement. *International Journal of Educational Sciences, 5*(1), 69-74.

O'Day, J. A. (2002). Complexity, accountability, and school improvement. *Harvard Educational Review*, 72(3), 293-329.

Oplatka, I. (2007). Principal's role in marketing the schools: Subjective interpretations and personal influences. *Planning and Changing*, 38 (3&4), 208-221.

Özer, N. & Beycioğlu, K. (2013). Paylaşılan liderlik ölçeğinin geliştirilmesi: geçerlik ve güvenirlik çalışmaları. *İlköğretim Online*, *12*(1), 77-86.

Portin, B., Schneider, P., De Armond, M., & Gundlach, L. (2003). *Making sense of leading schools: a study of the school principalship*. Center on Reinventing Public Education, University of Washington.

Sheppard, B. & Dibbon, D. (2010, January 5-8). *Improving the capacity of school system leaders and teachers to design productive learning environments*. Paper presented at 23rd International Congress for School Effectiveness and Improvement, Kuala Lumpur, Malaysia

Sheppard, B., Hurley, N., & Dibbon, D. (2010, April 30-May 4). *Distributed leadership, teacher morale, and teacher enthusiasm: unraveling the leadership pathways to school success*. Paper presented at the Annual Meeting of the American Educational Research Association, Denver, Colorado.

Silins, H. & Mulford, W. (2002). Leadership and school results. In: K. Leithwood, & P. Hallinger (Eds.), *Second International Handbook of Educational Leadership and Administration* (pp. 561-612). Kluwer.

Smith, L. M. (2007). *Study of teacher engagement in four dimensions of distributed leadership in one school district in Georgia* (Doctor of education dissertation, Georgia Southern University, Statesboro, GA).

Spillane, J. P. (2006). *Distributed Leadership*. Jossey-Bass.

Spillane, J. P., Camburn, E. M., & Pareja, A. S. (2007). Taking a distributed perspective to the school principal's workday. *Leadership and Policy in Schools, 6*(1), 103–125.

Spillane, J. P., Halverson, R., & Diamond, J. B. (2004). Towards a theory of leadership practice: A distributed perspective. *Journal of Curriculum Studies*, *36*(1), 3-34.

Storey, A. (2004). The problem of distributed leadership in schools. *School Leadership and Management*, *24*(3), 249-265.

Tabachnick, B., & Fidell, G. (2103). *Using Multivariate Statistics.* Boston: Pearson.

Tahir, L. M., Lee, S. L., Musah, M. B., Jaffri, H., Said, M. N. H. M., & Yasin, M. H. M. (2016). Challenges in distributed leadership: Evidence from the perspective of headteachers. *International Journal of Educational Management*, 30(6), 848 - 863.

Timperley, H. (2005). Distributed leadership: developing theory from practice. *Journal of Curriculum Studies*, *37*(4), 395-420.

Weick, K. E. (1976). Educational organizations as loosely coupled systems. *Administrative Science Quarterly*, 21(1), 1-19.

Yetim, Z. (2016). İlköğretim kurumlarında dağıtımcı liderlik ile örgütsel bağlılık arasındaki ilişki: Seydikemer örneği. *Uluslararası Sosyal Araştırmalar Dergisi*, *9*(43), 1565-1572.

Yılmaz, D. & Turan, S. (2015). Dağıtılmış liderliğin okullardaki görünümü: bir yapısal eşitlik modelleme çalışması. *Kuram ve Uygulamada Eğitim Yönetimi, 21*(1), 93-126.

York-Barr, J. & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of Educational Research*, *74*(3), 255–316.

iojes

www.iojes.net

International Online Journal of Educational Sciences

ISSN: 1309-2707

The Role of Artificial Intelligence in the Development of Questioning Strategies of Middle School Mathematics Teacher Candidates

Research Article

Murat DURAN[1], Lina OZEN[2], Sedef CELIK DEMIRCI[3]

[1]Hatay Mustafa Kemal University, Department of Mathematics and Science Education, Hatay, Türkiye 0000-0002-4612-7117

[2]Hatay Mustafa Kemal University, Mathematics and Science Education, Hatay, Türkiye 0009-0000-8554-8259

[3]Artvin Çoruh University, Mathematics and Science Education, Artvin, Türkiye 0000-0002-9242-8009

To cite this article: Duran, M., Ozen, L., & Celik Demirci, S. (2026). The role of artificial intelligence in the development of questioning strategies of middle school mathematics teacher candidates. *International Online Journal of Educational Sciences*, *18*(1), 15-32.

ARTICLE INFO

Article History:

Received: 03.12.2025

Available online: 27.01.2025

ABSTRACT

This study examines the questions posed by middle school mathematics teacher candidates in the classroom, aided by artificial intelligence (AI) supported feedback. Thus, it reveals how AI influences the questioning strategies of teacher candidates. The research was conducted using an action research methodology, which is one of the qualitative research designs. The participants of the study were middle school mathematics teacher candidates enrolled in a teaching practice course. Based on the AI-supported feedback provided to the teacher candidates, the new questions they posed and the changes in the nature of these questions were analysed. The questioning strategies employed by the teacher candidates in mathematics classes were analysed using predetermined categories aligned with the theoretical framework. According to the findings of the research, the feedback received from AI contributed to the candidates' development of questions that encourage deeper thinking, create a discussion environment, and elicit student thinking, while also positively influencing their professional development.

Keywords:

Questioning, artificial intelligence, feedback, mathematics teaching, teacher candidate

Introduction

Human beings are inherently inclined to question and be curious, and this process of inquiry constitutes one of the fundamental dynamics of learning (Göçer & Kurt, 2022). Inquiry and curiosity play a crucial role in individuals' interactions with their environment, often manifesting as questions. The historical use of questions in the processes of knowledge acquisition and learning dates back to Socrates. Socratic pedagogy is built on strategically asking questions to reveal students' thinking abilities rather than directly transferring knowledge (Büyükalan-Filiz, 2009). In this context, questioning holds a significant place in the classroom as a

[1] Corresponding author's address: Hatay Mustafa Kemal Üniversitesi
e-mail: drmurat05@gmail.com
DOI: https://doi.org/10.15345/iojes.2026.01.002

supportive tool that enhances the learning experience. Effective questioning techniques in classroom instruction activate students' cognitive processes, making learning more meaningful and providing opportunities for deep thinking. The initiation of questioning about a subject triggers a cognitive processing cycle regarding that topic and supports students in structuring their knowledge (Özkan, 2011). In this cognitive process, the teacher's role emerges not only as a provider of information but also as a guide who encourages the development of students' thinking skills. Teachers should recognize the learning impact of the questions they ask and benefit from new methods to enhance their questioning skills accordingly (Bozkurt, Kılıç & Özmantar, 2017). Questions that encourage students to express diverse ideas, compare and connect these ideas to their own thoughts, and are designed to promote learning play a crucial role in enhancing the quality of the teaching process (Özaltun-Çelik & Bukova-Güzel, 2016). The contemporary educational approach that highlights artificial intelligence technology offers significant potential for teacher candidates to develop their questioning strategies in the context of critical thinking and creativity. In light of contemporary educational approaches and technological advancements, the potential of AI and related technologies to enhance teacher candidates' questioning strategies becomes increasingly important. Thus, this study aims to elucidate the role of artificial intelligence in the context of the questioning strategies employed by middle school mathematics teacher candidates.

Theoretical Framework

One of the most effective ways to achieve accurate knowledge in mathematics is the ability to ask effective and meaningful questions (Cumhur, 2016). In this regard, teachers' classroom questioning techniques play a significant role in revealing and supporting students' mathematical thinking processes (Mangwiro & Machaba, 2022). Additionally, the teacher's ability to decide when and how to use mathematical language and notations appropriately in accordance with students' thinking processes is also defined as an important competency area. The development of teacher candidates' inquiry-based thinking skills is valuable for both their own pedagogical competencies and the quality of their future students' learning processes (Kılıç & Erkuş, 2015). In light of innovations in educational programs, the role of the teacher has been redefined from a figure who simply transmits knowledge to a guide who questions, provokes thought, facilitates discussion, directs, and motivates (Bayır, 2020). Conversely, the student is positioned not as a passive listener in the learning process but as an active individual equipped with the skills of questioning, inquiry, problem formulation and solving, critical thinking, and collaborative learning (Arslan & Özpınar, 2008). In this context, questioning transcends a simple question-and-answer format; it is a fundamental skill essential for effective teaching. The acquisition of questioning skills during their student years will contribute to teacher candidates' professional competency development, allowing them to use these skills more efficiently and consciously (Cumhur, 2019). Consequently, the questioning strategies employed by teacher candidates can be regarded as a vital component of an effective teaching process.

Studies indicate that artificial intelligence (AI) has made significant contributions to education (İşler & Kılıç, 2021). The use of AI technologies in mathematics education supports educators and researchers in their goals to enhance the quality of teaching processes through the integration of AI into education (Kara, 2024). Furthermore, AI technologies contribute to teachers' decision-making processes by providing feedback on classroom situations and considering students' needs through personalized learning platforms (Salas-Pilco, Xiao & Hu, 2022). Additionally, these technologies offer personalized learning pathways for students, enabling teachers to analyse individual needs and abilities more effectively, thereby facilitating the development of predictive and self-regulated learning processes (Seyrek et al., 2024). In this context, AI technologies provide feedback tailored to students' needs, identifying errors and offering suggestions to improve the learning process (Gürlek et al., 2023). These studies demonstrate that AI plays a crucial role in personalizing students' learning processes and supporting teachers' decision-making processes.

Teachers can utilize artificial intelligence (AI) tools to generate questions that foster the development of higher-order thinking skills (Orhan-Göksün, 2025). The results obtained from AI tools and the data they provide will assist teachers in determining the best ways to utilize various resources (İşler & Kılıç, 2021). In particular, AI-based feedback helps teacher candidates quickly analyze the strengths and weaknesses of students' responses and develop more effective questions (Matelsky et al., 2023). This enables teacher candidates to better understand students' current levels of knowledge and gain the ability to tailor lesson content to individual students. Additionally, the personalized feedback provided by AI aids teacher candidates in developing their critical thinking skills and making classroom interactions more efficient (Kochmar et al., 2020). AI applications enhance the quality of instruction by enabling teacher candidates to closely monitor students even in large classrooms and conduct more accurate analyses of their learning processes (Riedl & Bogert, 2024). Thus, through the ability to analyse student responses, AI applications assist teacher candidates in understanding students' thinking processes and developing their skills in reshaping their questions.

Studies on the decisive role of teacher questions in the teaching process strengthen the theoretical foundations in this field. In this context, Boaler and Brodie (2004) consider teacher questions not only as tools for knowledge transfer but also as powerful pedagogical instruments that shape the learning environment. In their research, they categorized classroom questions into nine categories and analyzed how these questions affect students' thinking patterns and levels of engagement. They particularly argued, referencing Shulman's pedagogical content knowledge theory, that effective questioning requires a deep understanding of both subject matter knowledge and student knowledge.

In this study, the types of questioning developed by Boaler and Brodie (2004) will be used to examine questions. The reason for selecting this model is its contribution to students not only in recalling information but also in constructing meaning, engaging in deep thinking, and making connections. Additionally, its alignment with 21st-century skills and higher-order thinking skills, as well as its effectiveness as a practical tool in lesson planning, further justifies the choice of this model. Table 1 shows the types of questions developed by Boaler and Brodie (2004).

Table 1. Questioning categories created by Boaler and Brodie (2004)

Question Type	Explanation	Examples
1. Gathering information, guiding by demonstrating methods	It requires an immediate response. It reiterates known facts. It allows students to express facts.	"What is the value of x?" "How would you draw this point?"
2. Establishing terminology	It ensures the use of correct mathematical language.	"How would we write this correctly?" "What is this called?"
3. Exploring mathematical meanings and/or relationships	It points out basic mathematical relationships and meanings. It establishes connections between mathematical expressions and forms of representation.	"What is the percentage equivalent of this fraction?" "What is the relationship between the sides and angles in a right triangle?"
4. Unlocking students' thoughts	It asks students to explain, elaborate on, or clarify their ideas.	"Can you show us how you found it?" "So where did this number come from?"
5. Initiating discussion	It enables students to gather ideas from other students.	"Does anyone have another idea about this?" "What would your idea be?"
6. Making connections and applying them	It establishes connections between mathematical ideas and other subject/life areas.	"In what other conditions could you apply this?" "Where have you used this before?"
7. Expanding on thinking	It relates mathematical thinking to other similar situations.	"Would this work with other numbers?" "Could we solve a similar problem for triangles?"
8. Guiding and focusing	It helps students focus on the main elements or situation to solve the problem.	"What does the question ask you to do?"
9. Creating context	It connects mathematics to examples from daily life to make sense of it.	"What is the price of 100 TL with a 25% discount?"

The National Council of Teachers of Mathematics (NCTM, 1991) emphasizes the importance of teachers producing questions that allow students to clearly express their thoughts, justify them, and encourage inquiry. Studies in the literature show that the questions asked by teachers in the classroom play a significant role in students' learning and thinking processes (Franke et al., 2009; Kim, 2025; Tanışlı, 2013). However, it has been observed that teacher candidates use a limited range of question types that challenge students' thinking, open discussions on different solution paths, and deepen thought, often focusing instead on questions aimed at obtaining the correct answer from students (Tataroğlu-Taşdan & Didiş-Kabar, 2022). Similarly, studies examining the questioning behaviours of teacher candidates have revealed limitations in the diversity and quality of their questions (Cumhur, 2016). These findings suggest that teacher candidates face challenges in employing questioning strategies during classroom practices that effectively elicit student thinking and enhance the learning process. This deficiency can negatively impact students' mathematical reasoning and levels of classroom participation.

In particular, the lack of immediate and constructive feedback regarding the questions posed by teacher candidates during the practice process can perpetuate this issue. Despite instructional practices aimed at improving teacher candidates' questioning skills, it has been noted that these practices are generally not supported by detailed and individualized feedback (Bywater et al., 2025). In this context, it has been stated that AI tools provide immediate and targeted feedback to teacher candidates, contributing to their professional development processes (Uçar & Uçar, 2025). However, research on the impact of AI-supported feedback on the development of teacher candidates' questioning skills is limited. Therefore, examining how AI-based feedback affects candidates' questioning strategies has become increasingly important. Thus, the aim of this research is to investigate the role of artificial intelligence in the context of the questioning strategies employed by middle school mathematics teacher candidates.

Methodology

The role of artificial intelligence in the development of questioning strategies among middle school mathematics teacher candidates was examined using qualitative methods, specifically action research. According to Üredi and Doğanay (2023), action research is a cyclical process focused on identifying and improving problems in practice through qualitative data analysis. The rationale for selecting this method lies in its structure, which enables teacher candidates to enhance their classroom practices through iterative cycles. In this context, action research was conducted in weekly cycles aimed at improving the classroom practices of teacher candidates. Each week, the questions asked by teacher candidates in the classroom were recorded. These recordings were transcribed and prepared for analysis. The types of questions asked by the teacher candidates were identified through the transcripts, and the questions were evaluated according to the criteria established in the study. Based on the evaluation results, feedback was prepared for each teacher candidate regarding the questions that needed to be developed. This feedback was shared with the candidates during regular meetings. In the final phase, teacher candidates reorganized the questions and classroom lesson plans they would use for the following week with the help of the feedback they received. The process progressed within a repeating development cycle. Figure 1 shows the usage cycle of the action research method in this study.

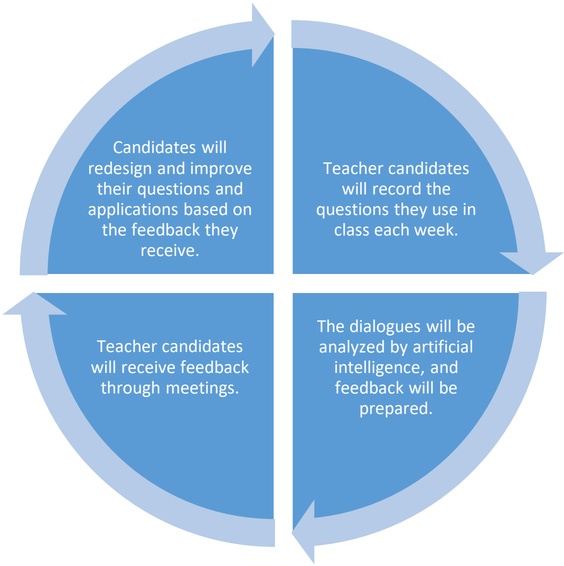

Figure 1. Steps of action research method

Participants

The participants consisted of senior teacher candidates enrolled in the Elementary Mathematics Teaching program at a state university located in the Eastern Black Sea Region, who were taking courses in teaching practice and mathematical communication. The study was conducted with four teacher candidates, including one male and three female participants, who volunteered to participate. The study took place during the spring semester of the 2024-2025 academic year. The participants were selected using a purposive sampling method, specifically convenience sampling, due to its appropriateness for the purpose of the study and ease of access (Palinkas et al., 2015). The researcher assigned codes to the candidates in the order of A1, A2, A3, and A4 to maintain the confidentiality of the teacher candidates' identities.

Data Collection Tools

In the data collection process of this study, multiple methods and tools were utilized. The development of teacher candidates' questioning skills was monitored through an interview form consisting of open-ended questions, which was created based on expert opinions. Prior to the main interviews, the purpose of the interviews and that the implementation was conducted within the framework of scientific research were clearly communicated to the teacher candidates. The interviews were conducted outside of class hours in the classroom of the university's Faculty of Education. Throughout the process, the researcher contributed to qualitative data by taking field notes along with audio recordings during the meeting interviews. Additionally, the questions obtained from the transcripts were evaluated using artificial intelligence, providing further feedback on the questioning strategies of the teacher candidates. The data collection tools used in the study are described in more detail below.

A) Semi-Structured Interview Form: The interview form prepared to assess the development of teacher candidates' questioning skills was originally developed by the researchers in line with the purpose of the study through a review of the relevant literature on questioning strategies and AI-supported feedback (Boaler & Brodie, 2004; Cumhur, 2019; Cumhur & Güven, 2018; Ismail et al., 2024; Mete et al., 2025). The interview form prepared to monitor the development of teacher candidates' questioning skills was finalized based on the opinions of field experts. Following a pilot application, the questions in the interview form were rearranged to be more suitable and understandable for measurement purposes. In this context, the items in the form that contained repetitive content and open-ended questions that could be answered with short and limited responses were restructured to include questions that would allow participants to express their views, thoughts, and experiences in detail, along with their justifications. The interview form prepared regarding "AI feedback" consists of 10 questions. Five of the questions are open-ended, while the other five consist of closed-ended questions that participants can mark as "never, sometimes, or always." During the interview process, the responses of the teacher candidates were collected in written form. Accordingly, the candidates wrote their answers on the interview form and submitted it to the researcher.

B) Audio Recordings: During the research process, the meetings conducted, each lasting approximately 30 minutes, were recorded. The audio recordings were used in the analysis process to prevent data loss. Before starting the interviews, the teacher candidates were informed that audio recordings would be made. Additionally, the participants' explicit consent was obtained through a "Voluntary Consent Form." The process of collecting audio recordings was carried out in accordance with the ethical approval obtained for the research. To ensure participant confidentiality, code names were used in the transcripts. The audio recordings and written data were securely stored to be accessible only to the researcher.

C) Field Notes: The researcher took notes by observing during meetings and classroom practices. The observations were conducted to monitor the questioning behaviours of teacher candidates and their classroom interactions. The researcher assumed a passive observer role during the observation process and did not intervene in the flow of the lesson. Brief notes taken during the lesson were later elaborated into descriptive field notes. The obtained field notes were used as supportive data.

D) AI Feedback: To develop the classroom questioning strategies of teacher candidates and provide constructive feedback on these questions, the GPT-4o model available through the ChatGPT Plus platform provided by OpenAI was utilized. All AI evaluations throughout the study were conducted using the same model. A structured prompt prepared by the researcher was used to evaluate the teacher candidates' questions and generate feedback without modifying ChatGPT's system prompt. The prompt provided to the AI was prepared based on the purpose of the study and the question categories developed by Boaler and Brodie (2004). The AI was instructed to evaluate each question according to the relevant category, justify its evaluation, and provide constructive feedback on how the question could be improved. To ensure consistency in the evaluations, a standard prompt template was used for all teacher candidates, and the structure of the prompt was not changed throughout the study. During this process, the teacher candidates' questions evaluated and the lesson topic differed.

Before the evaluation, the categories of questions used in the research were introduced to the artificial intelligence system, and the expected process to be followed during the evaluation was clearly outlined. Prior to the research, the teacher candidates were informed about the use of artificial intelligence. The data provided to the AI consisted of questions from teacher candidates obtained from classroom dialogues and transmitted without any modifications. AI was utilized as a tool for providing constructive feedback in this research. The feedback given by the AI included explanations and example suggestions for each question, offering recommendations aimed at improving the questioning strategies of the teacher candidates. During the interaction process with the AI, the researcher not only played the role of transferring the questions to the system but also organized the feedback obtained and presented it to the teacher candidates. The feedback provided by the AI was examined by the researcher, taking into account the original transcripts and the question categories used in the research. When deemed necessary, this feedback was also evaluated by experts in mathematics education. The suggestions and revised question examples included in the feedback provided by the AI were evaluated together with the teacher candidates, discussed in terms of their suitability for classroom implementation, and used in subsequent teaching practices. Since the same question was not submitted to the system again during the research, whether the responses given to the same question changed was not examined. The development of the teacher candidates was evaluated within the scope of an AI-supported and researcher-guided feedback process. Figure 2 shows an example of this feedback.

Question: "Can we construct a triangle using two angles and one side?"

Feedback:

A very good question that triggers deep thinking. However, more explanation should be requested from the student.

Improved Suggestion:

"Do you think we can draw two different triangles with the same information about angles and sides? If so, would they be congruent or just similar?"

Objective: to discover the distinction between **similarity, congruence, and possibility**.

Figure 2. An example of feedback provided by artificial intelligence

Data Collection Process

The data collection tools are planned according to weeks to ensure the data collection process is carried out systematically. Table 2 shows the stages of the data collection process and the weekly implementation plan.

Table 2. The stages of the data collection process and the implementation plan by week.

Week	Data Collection Tools
Week 1	Preliminary interview, Initial meeting with a semi-structured interview form, Audio recording.
Week 2	Introduction (Information about artificial intelligence and questioning strategies), Audio recording
Week 3	Introduction (Information about questioning strategies), Audio recording
Week 4	Teacher candidates' transcripts, Audio recording, AI feedback, Focus group interview
Week 5	Teacher candidates' transcripts, Audio recording, AI feedback, Focus group interview
Week 6	Teacher candidates' transcripts, Audio recording, AI feedback, Focus group interview
Week 7	Teacher candidates' transcripts, Audio recording, AI feedback, Focus group interview
Week 8	Final interview, Semi-structured interview form, Audio recording

As seen in Table 2, the data collection process lasted for eight weeks. In the first week, a preliminary interview was conducted to determine the existing questioning strategies and experiences of the teacher candidates. In the second and third weeks, the teacher candidates were informed about questioning strategies and AI-supported feedback. In each interview conducted, classroom interactions were recorded via audio. From the fourth to the seventh week, transcripts of the teacher candidates' classroom practices, audio recordings, and feedback obtained from the AI were regularly collected. During these weeks, focus group discussions were also held, and the candidates' experiences related to the process were recorded through audio. In the final week of the research, final interviews were conducted using a semi-structured interview form. In the last interview, the opinions of the teacher candidates regarding the changes they experienced throughout the process were collected via audio. Thus, the data were regularly collected in a manner that allowed for monitoring the changes in the questioning strategies of the teacher candidates throughout the process.

Data Analysis

In this research, the analysis of the obtained data utilized multiple data sources. In the initial phase of the study, questioning strategies and question categories developed by Boaler & Brodie (2004) were introduced to the teacher candidates. Then the initial observation data, collected without any feedback, were analysed to determine the current state of the candidates' questioning skills. Throughout the process, transcripts of classroom practices were regularly transferred to the artificial intelligence system each week, and feedback on the questions posed by the teacher candidates was obtained. The feedback received from the AI was considered a mediating factor that shaped the subsequent practices and reflections of the teacher candidates. Accordingly, the AI feedback related to the transcripts obtained each week was communicated to the teacher candidates, allowing for the monitoring of changes and developments in their questioning strategies.

In this study, content analysis was employed for the classification of question types during the data analysis process, while thematic analysis was used to reveal the developmental processes of the teacher candidates. This method facilitates the organization and rich description of data by breaking it down into meaningful components, while also allowing for deeper interpretation (Boyatzis, 1998). During the data analysis process, transcripts from classroom practices, interview responses, and field notes were evaluated together. The data were carefully examined to identify expressions with similar meanings, and coding was conducted based on these expressions. Expressions with similar meanings were first combined under the same code. Subsequently, sub-themes reflecting the common meanings of the codes were developed and revised where necessary. For example, the code "question revision process" was classified by the researcher under the theme "Thinking and Planning Skills," whereas the experts in mathematics education classified it under the theme "Implementation and Development." The participant statements associated with this code were re-examined, and it was determined that these statements focused more on evaluating and improving questions after classroom implementation than on the question preparation process. As a result of the evaluations, consensus was reached that the code should be classified under the theme "Implementation and Development." Similarly, other codes for which disagreements existed were re-evaluated by considering their context and theme definitions, and the coding framework was finalized. For example, the statements "I wrote down the questions I could ask before the lesson," "I planned the classroom dialogues while preparing the lesson plan," and "I became more careful about the questions I would ask" were grouped under the sub-theme "Planned Instruction." Similarly, the statements "encouraging students to think," "asking probing questions," and "questions supporting higher-order thinking" were grouped under the sub-theme "Strategic Use of Questions." No codes or themes were excluded or omitted during the coding process. The resulting codes and themes were examined by experts in mathematics education. The code contents, theme names, and code-theme matches were reviewed and finalized by considering the experts' evaluations. This process was intended to support the consistency and trustworthiness of the analysis. The use of multiple data sources during the analysis process enabled a multifaceted examination of the changes in the teacher candidates' questioning strategies. A flowchart of the data analysis process is presented in Figure 3.

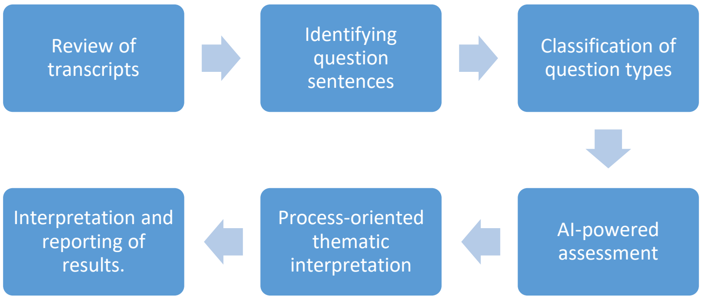

Figure 3. Data analysis process flowchart

In the diagram in Figure 3, the questions in the transcripts of the teacher candidates were identified and then classified according to their purposes in the teaching process. While evaluating the questions within the established categories, it was observed that some questions overlapped with multiple categories. In these cases, the purpose for which the questions were asked by the teacher candidates was considered a determining criterion. For example, questions such as "What were we doing to maintain the equality?" were asked more to continue the flow of the lesson and transition to the next procedural step rather than to elicit student thinking. In this context, the function of the questions in the teaching process was taken into account during the evaluation, and consensus was reached on the appropriate category.

Findings

The research findings are presented under two headings: "Teacher Candidates' Questioning Strategies in the Context of Feedback Received from Artificial Intelligence" and "The Role of Artificial Intelligence in the Questioning Strategies Used by Teacher Candidates in the Mathematics Learning-Teaching Process".

Teacher Candidates' Questioning Strategies in the Context of Feedback Received from Artificial Intelligence

The questions posed by the teacher candidates were examined weekly to determine the changes in teacher candidates' questioning strategies based on feedback received from the artificial intelligence. The classroom practices from the fourth, fifth, sixth, and seventh weeks, during which the teacher candidates actively taught, were systematically numbered in the findings section as the first, second, third, and fourth weeks to facilitate the analysis. In this context, 236 questions were obtained from the classroom practices of the teacher candidates and evaluated. These questions were analysed under nine categories: Information Gathering - Method Demonstration (K1), Establishing Terminology (K2), Exploring Mathematical Meanings and/or Relationships (K3), Eliciting Students' Thoughts (K4), Initiating Discussion (K5), Making Connections and Application (K6), Expanding Thought (K7), Guiding and Focusing (K8), and Contextualizing (K9). Table 3 shows the distribution of the number of questions for each teacher candidate.

Table 3. The distribution of the number of questions asked by teacher candidates, by week and category

Teacher Candidates	Weeks	K1	K2	K3	K4	K5	K6	K7	K8	K9
A1	Week 1	8	0	2	0	0	0	0	0	0
	Week 2	2	1	3	0	0	1	0	1	0
	Week 3	2	1	7	2	2	0	0	3	0
	Week 4	1	1	1	2	0	1	1	3	1
A2	Week 1	11	1	1	3	0	0	0	4	0
	Week 2	9	0	1	3	1	0	2	3	0
	Week 3	5	0	1	1	0	0	5	1	1
	Week 4	2	3	4	3	2	1	1	2	1

A3	Week 1	14	2	6	1	0	0	0	0	0
	Week 2	3	1	6	1	2	2	0	0	0
	Week 3	4	4	1	2	2	1	0	1	0
	Week 4	4	2	5	1	2	1	2	2	2
A4	Week 1	2	0	0	2	1	0	0	0	0
	Week 2	2	0	0	1	0	1	1	1	0
	Week 3	2	2	0	3	2	1	2	1	1
	Week 4	1	2	1	3	1	1	4	2	2

According to Table 3, it is evident that the number and types of questions posed by the teacher candidates varied over the four weeks. A1's questions in the first week predominantly focused on the K1 category; however, as the weeks progressed, it became apparent that A1 began to ask questions from other categories as well. Notably, the questions were approximately evenly distributed across all categories in the fourth week. Thus, A1 increased the diversity of questions during this process, moving away from asking only unidirectional questions. A2, on the other hand, focused on different categories from the beginning of the process, emphasizing different categories each week. A2 made gradual progress, asking questions suitable for all categories in the fourth week. A3, who emerged as the candidate asking the most questions, had most of their questions in the K1 category during the first week. As the weeks progressed, A3 began to ask questions that aligned with most categories, particularly in the third and fourth weeks, where questions suitable for each category were noted. A4 initially stood out as the candidate asking the fewest questions. The few questions posed by A4 were categorized under K1, K4, and K5. However, it was observed that A4 increased the number of questions towards the end of the process, particularly in the last week, where A4 asked questions suitable for each category.

When evaluating all four teacher candidates together, it was observed that all candidates initially concentrated primarily on the K1 category. As the process progressed, the candidates began to ask questions from different categories. Notably, A1 and A4 exhibited a significant increase in question diversity in the last week compared to the first week. A2 consistently focused on different categories each week, while A3 maintained a steady approach in asking questions suitable for the categories. The teacher candidates were seen to pose information-based and directly answerable questions at the beginning of the process. An increase in the diversity of questions asked by the teacher candidates was observed in the second and third weeks. In the last week, this increase in category diversity was distributed evenly. Accordingly, towards the end of the process, the candidates posed questions from different categories that required interpretation, explanation, and comparison, in line with their knowledge levels. Thus, the process indicates that the teacher candidates diversified their questioning skills and asked questions suitable for different cognitive domains. This change, quantitatively presented in Table 2, is visually supported in Figure 3, which shows the category-based distribution of questions posed by the teacher candidates across the weeks. Figure 4 shows the distribution of questioning strategies by week.

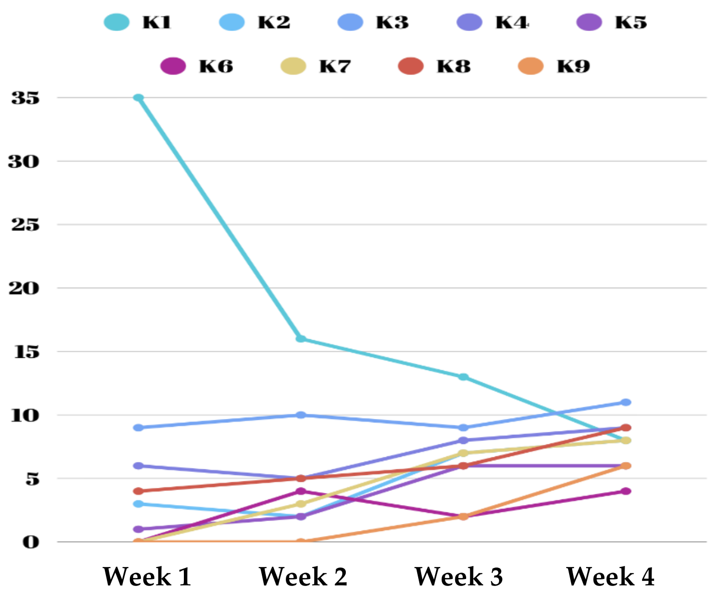

Figure 4. Category changes by week

According to the distribution of questions posed by week, there are distinct changes in the questioning strategies of the candidates. In the first week, the questions were generally knowledge-based or directed towards a single answer. These questions reflect the questioning approach of the first week, as they aimed more at recalling and verifying information rather than eliciting the students' thinking processes. Below are some examples of the questions posed by the teacher candidates in the first week:

***A1:** What is the Pythagorean theorem?*

***A2:** What do we call polygons that have all angles equal and all opposite sides of equal length?*

***A3:** What was the diagonal?*

***A4:** Is there anything you'd like me to tell you?*

The questions posed by the teacher candidates in the classroom were categorized under "Information Gathering - Method Demonstration (K1)." Following the feedback from the artificial intelligence and the question renewal processes in the second week, there has been an increase in the diversity of question categories among the teacher candidates. They particularly focused on questions that required justification and encouraged thinking. According to the table, there was a notable increase in questions belonging to the K5, K6, and K7 categories. In this context, some questions from the second week have been selected as example questions due to their prominence in reflecting the emerging questioning tendencies. Below are some of the questions posed by the teacher candidates in the second week:

A1: *Does this triangle resemble the triangle we discussed in a previous lesson? Why?*

A2: *Why don't you agree with your friend?*

A3: *Do you think that's right? Can everyone express their opinion?*

A4: *Does anyone want to show a different rectangle?*

The questions provided as examples for the second week are categorized under "Initiating Discussion (K5)," "Making Connections and Application (K6)," and "Expanding Thought (K7)." The distribution of questions posed by the teacher candidates was more balanced across categories in the third week. During this week, the candidates began to ask explanatory and in-depth questions that aimed to uncover the students' thinking processes, moving beyond just knowledge-based inquiries. In this context, some questions from the third week have been selected as examples due to their tendency to deepen students' thinking processes and require recognition of mathematical relationships, as well as their representation of different categories compared to the first two weeks. Below are some example questions from the third week:

A1: *Okay, but if these triangles were right triangles, how would we find the length of side AB?*

A2: *We are older than you now. What would the average age be? Who wants to share their opinion?*

A3: *What do we do when it's an even number?*

A4: *So, what is the relationship between the side lengths and areas of rectangles that have the same perimeter?*

It is evident that the teacher candidates asked questions that required students to explain their solution processes, make connections, and think about different situations. The example questions belong to the categories of "Establishing Terminology (K2)," "Exploring Mathematical Meanings and/or Relationships (K3)," and "Eliciting Students' Thoughts (K4)." In the fourth week, the distribution of questions was the most balanced compared to previous weeks. This week, there was a notable increase in the number of questions from the K7 and K9 categories. It was observed that the candidates focused on questions requiring mathematical explanations, aimed at multiple solutions, and capable of creating a discussion environment. Below are some example questions from the fourth week:

A1: *What needs to happen for the scales to be balanced?*

A2: *What is the possible relationship between road length and wheel size?*

A3: *Look! What does the shape gradually begin to resemble?*

A4: *What were our initial values, and how have they changed?*

It is clear from the example questions that the teacher candidates posed questions that expected students to establish mathematical relationships, provide explanations, and engage in discussions based on different perspectives. These questions indicate that the candidates' understanding of questioning has evolved to support higher-level cognitive processes compared to previous weeks. The example questions provided for the fourth week have been categorized under "Expanding Thought (K7)," "Guiding and Focusing (K8)," and "Contextualizing (K9)."

The Role of Artificial Intelligence in the Questioning Strategies Used by Teacher Candidates in the Mathematics Learning-Teaching Process

The example questions illustrate how the teacher candidates shaped their inquiries as the weeks progressed. This demonstrates the change in their questioning skills alongside the development process in their teaching practices. The areas of development identified, along with their sub-themes, were created by the researcher through an analytical evaluation of the data obtained from interview forms and audio recordings, complemented by graphs and example questions. In this context, the development of the teacher candidates has been categorized under five main headings (Figure 5):

- Pedagogical Skills
- Thinking and Planning Skills
- Communication and Interaction
- Application and Development
- Development with Technology

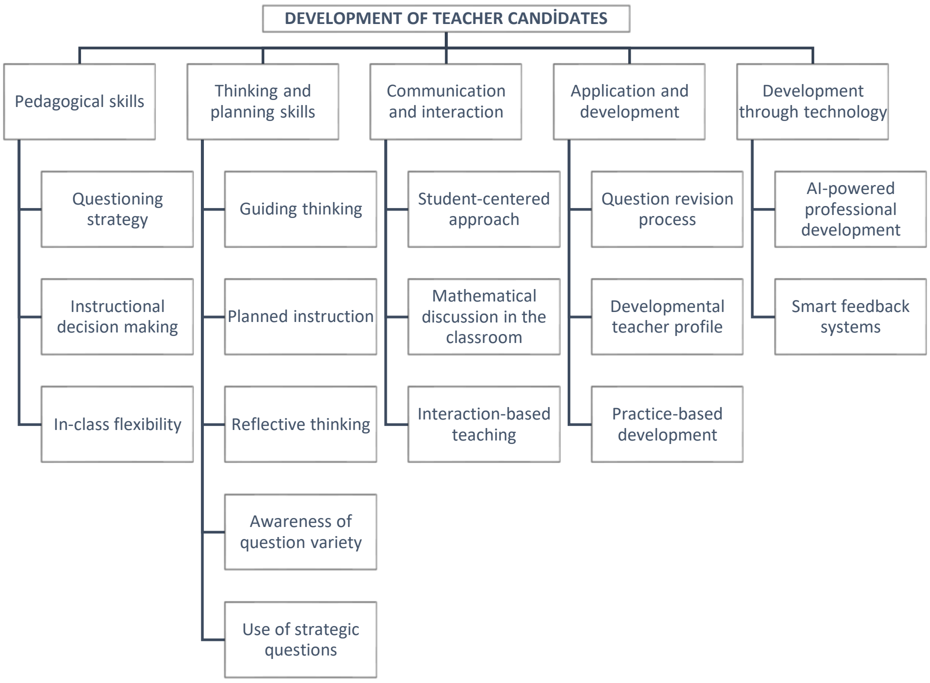

Figure 5. Development of teacher candidates

Figure 5 shows the progress of the candidates throughout the process. The five areas of development here not only reflect the evolution of the questions posed by the candidates but also demonstrate the advancements in their perspectives on teaching, preparation phases, and classroom applications. When examining the development of pedagogical skills in terms of questioning strategies, it was noted that the candidates began to see the questions they asked in class less as a means to elicit students' factual knowledge and more as a teaching tool that reveals students' thinking processes. For instance, A3 commented on this situation, stating, "Although the questions I asked in class were generally closed-ended, I started to ask exploratory questions that prompted students to think more due to the feedback I received," thereby supporting the evaluation of this impact on their questioning style.

When examining the development of thinking and planning skills regarding questioning strategies, it was observed that the candidates began to prepare lesson plans by identifying questions that could be asked appropriately in advance. In this context, they started to develop planned questions aimed at anticipating students' potential errors and revealing conceptual relationships. With the researcher noticing these developments during the process, the candidates also mentioned this skill during the final interview. For example, A4 stated, "I wasn't paying as much attention to my questions before. When I reviewed the questions I asked in the first week, I realized I was inadvertently leading the questions. Therefore, I noted down the questions I could ask before the lesson and tried to use them during class. I really saw that it worked."

Additionally, when examining the development of communication and interaction skills, it was observed that candidates began to enrich the dialogues they established with students by using questions that support thinking and require follow-up, rather than relying on closed-ended questions. For instance, A1 remarked, "As a result of this process, while I sometimes directly requested information feedback from students, I experimented with asking questions about how they understood the mathematical concepts in their minds and what schemas were forming." Similarly, A2 indicated, "After our meetings, I planned the dialogues I would establish in class while preparing the lesson plan." A4 also expressed, "I realized how important student-student and teacher-student communication is during the lesson delivery process. The more we utilize these dialogues in class, the more interaction we have." These statements illustrate that the teacher candidates focused on students' thinking processes and strengthening classroom interaction while also becoming aware of the impact of questioning on their communication. This awareness has also reflected in the application process, where it was observed that teacher candidates critically evaluated their teaching practices and developed their ability to revise their plans accordingly. During the application process, they recognized their shortcomings and errors, adjusting their questions with feedback.

Finally, when examining the development related to development with technology, it was found that teacher candidates improved their abilities to integrate feedback from artificial intelligence into their teaching processes, enhance lesson plans, diversify question examples, and generate questions suitable for different levels of thinking. In this context, A2 stated, "Artificial intelligence provides different ideas," A1 noted, "There is unlimited information and a variety of questions; it can produce questions that can further develop students," and A3 mentioned, "The feedback from artificial intelligence consisted of exploratory questions that encouraged students to think more." Collectively, these comments indicate that the feedback from artificial intelligence contributed to the development of the candidates' teaching processes.

Discussion, Conclusion and Recommendations

A significant change in the questions posed by the candidates throughout the process has been observed in this study examining the role of artificial intelligence in the development of questioning strategies among teacher candidates. Candidates have reshaped their questions qualitatively and posed them in the classroom environment. According to the findings, it can be said that while teacher candidates initially used questions primarily as a tool for guiding students through information gathering and method demonstration, they progressively began to utilize these questions as a pedagogical approach that reveals students' thoughts and deepens learning.

Some studies indicate that teacher candidates typically focus on questions aimed at recalling information and checking procedural steps while using higher-order thinking questions in a limited manner (Cumhur & Güven, 2018; Tanışlı, 2013). This may stem from the fact that teacher candidates view questioning primarily as a tool for information transmission and are limited in their skills related to pedagogical planning and classroom interactions. However, in this study, it was noted that teacher candidates reconsidered their questioning strategies, taking into account their existing limitations, and began to focus on different types of questions that would support the learning process. By the end of the process, it was observed that the diversity of questions was balanced and that the questions were more aligned with the learning objectives. In this situation, candidates may have incorporated potential questions into their lesson plans and increased the diversity of questions based on the different responses received from students in the classroom.

Thus, it can be said that The findings suggest that the artificial intelligence–supported feedback process contributed to the development of cognitive awareness among teacher candidates. Furthermore, it can be stated that this feedback contributed to helping candidates consider various ways of thinking and produce purpose-appropriate questions. Similarly, it is emphasized that feedback from artificial intelligence allows teachers to plan their teaching strategies with greater awareness (Mete et al., 2025). Additionally, studies on the use of artificial intelligence in education indicate that AI is viewed as a tool that can support teacher candidates in planning their teaching processes and pedagogical practices (Ismail et al., 2024).

It is observed that the questions posed by teacher candidates initially primarily fell into the categories of information gathering and method demonstration, indicating that they asked questions that could be answered directly. This finding aligns with Şahbaz and Kula-Ünver's (2024) conclusion that although teachers recognize their questioning skills, they fall short in using these skills in a planned and conscious manner. However, it was observed that teacher candidates began to ask questions from different categories through the artificial intelligence-supported feedback applied during the process. Notably, it was determined that the diversity of question categories was consistently distributed by the last week of the study. This result is consistent with Bozkurt and Polat's (2018) finding that candidates increasingly used more explanatory, discussion-provoking, and thought-deepening questions, as opposed to questions that did not provide guidance or justification.

This change in the quality of the questions asked can be associated with the advantages that artificial intelligence offers to educators in the teaching process. Çelik et al. (2022) stated that artificial intelligence is generally beneficial for teachers' instruction, thus contributing to planning, implementation, and evaluation. Feyzi et al. (2023) noted that AI tools are beneficial in teacher education in terms of providing feedback, enhancing instructional materials, and increasing student-teacher interaction. It has been emphasized that educators can utilize artificial intelligence models, such as ChatGPT, to create more creative, comprehensive, and effective materials that enhance student learning (Baidoo-Onu & Owusu-Ansah, 2023; Orhan-Göksün, 2025). Demir and Beyazhançer (2024) explained that artificial intelligence education increases teacher candidates' confidence in and skills for using this technology, positively affecting their self-efficacy perceptions. The results regarding the contributions of artificial intelligence education to teaching in the literature are consistent with the findings of this study.

In conclusion, the feedback provided and the systematic observation process have helped enhance teacher candidates' pedagogical awareness, enabling them to develop purpose-driven questions centered on student thinking. Thus, the study demonstrates that utilizing AI feedback to improve questioning skills can significantly contribute to the teacher education process. Based on the research, the changes in teacher candidates’ questioning skills were evaluated over a four-week implementation period, during which development was observed. However, this timeframe is limited for examining the long-term effects of AI feedback and making definitive inferences regarding the sustainability of these skills. Additionally, only the Boaler and Brodie (2004) model was used for classifying questions.

The findings of the present study point to important directions for future research. Extending the duration of the intervention would enable a more comprehensive examination of the sustainability and long-term effects of artificial intelligence–generated feedback. Moreover, comparative investigations involving different artificial intelligence tools could clarify their differential effects on questioning skills and help identify the forms of AI-generated feedback that are most effective in supporting skill development.

REFERENCES

Arslan, S., & Özpınar, İ. (2008). Teachers qualifications: Comparison between primary school curriculum expectations and teachers acquisitions in education faculties. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 2*(1), 38-63. https://dergipark.org.tr/tr/download/article-file/39761

Baidoo-Onu, D., & Owusu-Ansah, L. (2023). Education in the era of generative artificial intelligence (AI): Understanding the potential benefits of ChatGPT in promoting teaching and learning. *Journal of Artificial Intelligence, 7*(1), 52-62. https://doi.org/10.61969/jai.1337500

Bayır, M. (2020). Biopower and self-techniques in Michel Foucault. *Nosyon: International Journal of Society and Culture Studies,* (*6*), 1-13. https://dergipark.org.tr/en/download/article-file/1385688

Boaler, J., & Brodie, K. (2004, October). The importance, nature and impact of teacher questions. In *Proceedings of the twenty-sixth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 774-782). Chicago, IL: University of Illinois at Chicago. https://docdrop.org/download_annotation_doc/Boaler-Brodie-Questioning-cp9i8.pdf

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Sage Publications. https://books.google.com.tr/books?id=_rfClWRhIKAC&printsec=frontcover&redir_esc=y#v=onepage&q&f=false

Bozkurt, A., Kılıç, P., & Özmantar, M. F. (2017). An investigation of the question types in mathematics instruction of middle school classrooms. *Yıldız Journal of Educational Research, 2*(1), 1-29. https://dergipark.org.tr/tr/download/article-file/2088927

Bozkurt, A., & Polat, S. (2018). An examination of the teacher's questions for revealing students' mathematical thinking. *Turkish Journal of Computer and Mathematics Education (TURCOMAT), 9*(1), 72-96. https://doi.org/10.16949/turkbilmat.337419

Büyükalan-Filiz, S. (2009). The effect of catechetical method on the knowledge of teacher's interrogation and the technique of interrogation. *Kafkas University Journal of the Institute of Social Sciences, 1*(3), 167-195. https://dergipark.org.tr/en/download/article-file/116099

Bywater, J. P., Lilly, S., Datta, D., Ansari, S., Mohammad, A., Watson, G. S., ... & Chiu, J. L. (2025). The role of automated post-rehearsal feedback on pre-service mathematics teacher questioning. *The Journal of Applied Instructional Design*, *14*(2), 211-219. https://doi.org/10.59668/2222.21458

Cumhur, F. (2019). The role of questioning in teaching: How to develop questioning skills?. *Erzincan University Journal of Education Faculty, 21*(3), 32-55. https://doi.org/10.17556/erziefd.457560

Cumhur, F. (2016). *Examination development of pre-service mathematics teachers' questioning behaviours: A lesson study*. Unpublished Doctoral Dissertation. Karadeniz Technical University, Trabzon, Türkiye. (Dissertation Number: 448313). https://tez.yok.gov.tr/UlusalTezMerkezi/tarama.jsp

Cumhur, F., & Güven, B. (2018). Investigating of pre-service mathematics teachers' questioning: The reflections from teaching practice course. *Journal of Computer and Education Research, 6*(12), 195-221. https://doi.org/10.18009/jcer.432559

Çelik, I., Dindar, M., Muukkonen, H., & Järvelä, S. (2022). The promises and challenges of artificial intelligence for teachers: A systematic review of research. *Tech Trends*, *66*(4), 616-630. https://doi.org/10.1007/s11528-022-00715-y

Demir, B., & Beyazhançer, R. (2024). Investigation of artificial intelligence self-efficacy of prospective elementary mathematics teachers in terms of some variables. *International Journal of Social and Humanities Sciences Research, 11*(113), 2393-2398. https://doi.org/10.5281/zenodo.14279357

Franke, M. L., Webb, N. M., Chan, A. G., Ing, M., Freund, D., & Battey, D. (2009). Teacher questioning to elicit students' mathematical thinking in elementary school classrooms. *Journal of Teacher Education*, *60*(4), 380-392. https://doi.org/10.1177/0022487109339906

Göçer, A., & Kurt, A. (2022). Bibliometric analysis of graduate theses prepared on asking questions. *Mehmet Akif Ersoy University Journal of The Institute of Educational Sciences, 10*(13), 40-70. https://dergipark.org.tr/en/download/article-file/2412472

Gürlek, Y., Bozkoyun, E., Ulutürk, M., & Zeyrekgündüz, F. (2023). The effects and applications of artificial intelligence in education. *International Journal of Original Educational Research*, *1*(1), 25-132. https://ijoedu.com/index.php/pub/article/view/26/15

Ismail, A., Aliu, A., Ibrahim, M., & Sulaiman, A. (2024). Preparing teachers of the future in the era of artificial intelligence. *Journal of Artificial Intelligence, Machine Learning and Neural Network*, *44*, 31-41. https://doi.org/10.55529/jaimlnn.44.31.41

İşler, B., & Kılıç, M. (2021). The use and development of artificial intelligence in education. *e-Journal of New Media, 5*(1), 1-11. https://doi.org/10.17932/IAU.EJNM.25480200.2021/ejnm_v5i1001

Kara, E. (2024). Artificial intelligence in 21st century mathematics education: Global strategies in technological transformation. *Journal of Children and Civilization, 9*(15), 8-43. https://doi.org/10.47646/CMD.2024.334

Kılıç, D., & Erkuş, B. (2015). Classroom teachers' questionning strategies and the problems they encounter. *MANAS Journal of Social Studies, 4*(5), 230-243. https://dergipark.org.tr/en/download/article-file/577293

Kim, J. (2025). Anticipated and implemented questioning in mathematical discussions by prospective teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, *21*(4), 1-12. https://doi.org/10.29333/ejmste/16219

Kochmar, E., Vu, D. D., Belfer, R., Gupta, V., Serban, I. V., & Pineau, J. (July, 2020). Automated personalized feedback improves learning gains in an intelligent tutoring system. In *Artificial Intelligence in Education: 21st International Conference* (pp. 140-146). Ifrane, Morocco. https://doi.org/10.1007/978-3-030-52240-7_26

Mangwiro, C., & Machaba, F. (2022). Teacher questioning techniques to elicit learners' mathematical thinking. *The International Journal of Science, Mathematics and Technology Learning*, *30*(1), 51. https://doi.org/10.18848/2327-7971/CGP/v30i01/51-66

Matelsky, J. K., Parodi, F., Liu, T., Lange, R. D., & Kording, K. P. (2023). A large language model-assisted education tool to provide feedback on open-ended responses. *arXiv preprint arXiv:2308.02439*. https://doi.org/10.48550/arXiv.2308.02439

Mete, H., Uzal, G., Kılıç, E., & Erdem, A. (2025). Evaluation of artificial intelligence applications in education. Artun, O. (Ed.), *New Horizons in Technology and Education: Artificial Intelligence Integrations* (pp. 1-42). Ankara: Ubak Publishing. https://doi.org/10.5281/zenodo.15323873

National Council of Teachers of Mathematics [NCTM]. (1991). *Professional standards for teaching mathematics*. Reston, VA: NCTM Publications. https://www.nctm.org/members-only/?rurl=%2fStandards-and-Positions%2fMore-NCTM-Standards%2fProfessional-Teaching-Standards-(1991)%2f

Orhan-Göksün, D. (2025). SWOT analyses for the use of artificial intelligence tools in question activities to develop higher order thinking skills of pre-service teachers. *Erzincan University Journal of Education Faculty, 27*(2), 278-293. https://doi.org/10.17556/erziefd.1648080

Özaltun-Çelik, A., & Bukova-Güzel, E. (2016). A mathematics teacher's questioning approaches for revealing students' thinking during lesson study. *Turkish Journal of Computer and Mathematics Education, 7*(2), 365-392. http://doi.org/10.16949/turcomat.67541

Özkan, H. H. (2011). The level of teachers' questions and students' answers in maths classes. *Electronic Journal of Social Sciences, 10*(35), 64-81. https://dergipark.org.tr/en/download/article-file/70242

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research, 42*(5), 533–544. https://doi.org/10.1007/s10488-013-0528-y

Riedl, C., & Bogert, E. (2024). Effects of AI feedback on learning, the skill gap, and intellectual diversity. *arXiv preprint arXiv:2409.18660*. https://doi.org/10.48550/arXiv.2409.18660

Salas-Pilco, S. Z., Xiao, K., & Hu, X. (2022). Artificial intelligence and learning analytics in teacher education: A systematic review. *Education Sciences*, *12*(8), 569. https://doi.org/10.3390/educsci12080569

Seyrek, M., Yıldız , S., Emeksiz , H., Şahin , A., & Türkmen , M. T. (2024). Teachers' perceptions on the use of artificial intelligence in education. *International Journal of Social and Humanities Sciences Research, 11*(106), 845-856. https://doi.org/10.5281/zenodo.11113077

Şahbaz, A., & Kula-Ünver, S. (2024). The views of secondary school mathematics teachers on their questioning approaches used in teaching processes. *Journal of Necmettin Erbakan University Ereğli Faculty of Education, 6*(2), 740-762. https://doi.org/10.51119/ereegf.2024.105

Tanışlı, D. (2013). Preservice primary school mathematics teachers' questioning skills and knowledge of students in terms of pedagogical content knowledge. *Education & Science, 38*(169), 80-95. https://doi.org/10.15390/ES.2013.1159

Tataroğlu-Taşdan, B., & Didiş-Kabar, M. G. (2022). Pre-service mathematics teachers' responding to student thinking in their teaching experiences. *Journal of Pedagogical Research*, *6*(1), 87-109. https://doi.org/10.33902/JPR.2022175553

Uçar, F. M., & Uçar, M. B. (2025). Artificial intelligence-supported history of science instruction: An exploration of pre-service teachers' 21st century skills and learning experiences. *Başkent University Journal of Education, 12*(Özel Sayı), 95-114. https://dergipark.org.tr/en/download/article-file/5110908

Üredi, P., & Doğanay, A. (2023). Developing the skill of associating mathematics with real life through realistic mathematics education: An action research. *Journal of Theoretical Educational Sciences, 16*(2), 394-422. https://doi.org/10.30831/akukeg.1214339

iojes

www.iojes.net

International Online Journal of Educational Sciences

ISSN: 1309-2707

Fifth-Grade Students' Conceptions of Engineering: A Phenomenological Study

Research Article

Bahadir GULCU[1], Cezmi UNAL[2]

[1]Tokat Gaziosmanpaşa University, Department of Mathematics and Science Education, Tokat, Türkiye 0000-0003-2693-2909

[2]Tokat Gaziosmanpaşa University, Department of Mathematics and Science Education, Tokat, Türkiye 0000-0002-6894-2286

To cite this article: Gulcu, B., & Unal, C. (2026). Fifth-grade students' conceptions of engineering: A phenomenological study. *International Online Journal of Educational Sciences*, *18*(1), 33-44.

ARTICLE INFO

Article History:

Received: 23.12.2025

Available online: 28.01.2026

ABSTRACT

This research explores the initial mental models and conceptual perceptions of middle school fifth-grade students regarding the concepts of "engineer" and "engineering" using a phenomenological approach. The study group consists of 16 students from a socioeconomically disadvantaged region who had not previously received formal training in STEM, 3D design, or robotics. Data were collected through semi-structured interviews and "Draw-an-Engineer" tasks. Content analysis revealed that students primarily perceive engineering as a product-oriented profession centered on construction and repair, rather than a systematic cognitive problem-solving process. These findings highlight the prevalence of stereotypical images and the need for conceptual bridge-building before implementing formal engineering activities in science education.

Keywords:

Engineering perception, middle school students, phenomenological study

Introduction

The educational demands of the 21st century have undergone a paradigm shift, moving away from rote memorization toward a framework that emphasizes the integration of disparate fields to solve multifaceted global issues. As societies face increasingly complex challenges—ranging from climate change to rapid digitalization—the necessity for individuals to possess interdisciplinary literacy has never been more critical (Tytler, 2020). Within this landscape, Science, Technology, Engineering, and Mathematics (STEM) education has emerged not merely as a pedagogical trend but as a fundamental reform in global education policy. Among the components of STEM, "Engineering" (E) acts as the operational core, providing a structured methodology where scientific principles and mathematical logic are applied to develop tangible solutions for human needs (Opara et al., 2006; Polat et al., 2020). However, the successful implementation of engineering in K-12 settings, particularly in the pivotal transition year of the fifth grade, remains contingent upon understanding the existing mental frameworks of students. Without a clear picture of how young learners

[1] Corresponding author's address: Tokat Gaziosmanpaşa Üniversitesi
e-mail: cezmiunal@gmail.com
DOI: https://doi.org/10.15345/iojes.2026.01.003

conceptualize "the engineer" and "the engineering process," pedagogical interventions risk being misaligned with students' cognitive starting points (Mohammadi-Aragh et al., 2025).

Theoretical Perspectives on Mental Models: Piaget and Vygotsky

The formation of students' perceptions regarding engineering can be fundamentally understood through the lenses of cognitive and social constructivism. According to Piaget's theory of cognitive development, children construct mental models—or "schemata"—as they interact with their environment (Piaget, 1929). When students encounter the concept of engineering, they attempt to assimilate this new information into their existing cognitive structures. If their previous experiences are limited to observing physical construction or mechanical repairs, their mental models of engineering naturally solidify around these tangible activities. The findings of this study reflect a state of "disequilibrium," where students' existing schemata are often insufficient to encompass the abstract and systematic nature of the engineering design process, necessitating pedagogical interventions that facilitate cognitive "accommodation."

Furthermore, Vygotsky's sociocultural theory emphasizes that mental models are not constructed in isolation but are deeply influenced by the social and cultural tools available to the learner (Vygotsky, 1978). Vygotsky's concept of the "Zone of Proximal Development" (ZPD) suggests that a child's understanding of engineering is shaped by societal narratives, media representations, and the observations they make within their immediate community. In disadvantaged or rural contexts, the "more knowledgeable others"—such as parents, peers, or local professionals—may provide a limited scope of engineering as a vocation, thereby anchoring the student's conceptual development to localized stereotypes (Vosniadou & Brewer, 1992). Strengthening the pedagogical infrastructure of science education requires bridging this gap through scaffolded experiences that transition students from their spontaneous, everyday concepts of engineering toward more scientific and systematic understandings.

The Importance of Early Engineering Education

A significant body of international literature suggests that children's views of engineering are frequently narrow and heavily influenced by societal stereotypes (Xu & Jack, 2023). Landmark studies, such as those conducted by Cunningham et al. (2007) and Capobianco et al. (2011), have demonstrated that young learners often conflate engineering with manual labor or skilled trades. In the eyes of many students, an engineer is primarily a "fixer" or a "builder"—someone who repairs car engines or constructs skyscrapers. This "technician-centric" view fails to capture the creative, design-oriented, and social aspects of the profession (Dobela & Seboni, 2023, Polat et al., 2020). Furthermore, the use of the "Draw-an-Engineer Test" (DAET) across various cultures has revealed deeply rooted gender and racial stereotypes. The archetypal engineer in these drawings is typically a male figure, often depicted in a hard hat (baret), working in isolation within a construction or industrial setting. Such imagery not only misrepresents the collaborative and digital nature of modern engineering but also alienates students who do not see themselves reflected in these traditional depictions (Robinson et al., 2023). This study seeks to explore how these stereotypes manifest in a specific Turkish educational context, particularly before students are introduced to modern tools like 3D design and robotics.

Conceptual Misconceptions and Stereotypes in Engineering Perceptions

To delve beneath the surface of engineering perceptions, this research employs a phenomenological qualitative design. Phenomenology is uniquely suited for this inquiry as it focuses on the "essence" of a phenomenon as experienced by a specific group (Eberle, 2014). In the context of this study, engineering is the phenomenon, and the 5th-grade students are the experiencers. Their understanding is not just a collection of facts but a subjective reality built from various sources: family backgrounds, media representations, and prior school activities. By utilizing semi-structured interviews and mental images (drawings), we aim to capture the "lifeworld" of the student. Interviews allow for the exploration of the nuances in their verbal definitions, while drawings provide a window into their subconscious associations and visual mental models. This dual-method approach ensures a comprehensive triangulation of data, providing a rich, "thick description" of the students' conceptual landscapes (Eberle, 2014).

A unique dimension of this research is its placement within the "Science, Engineering, and Entrepreneurship" (FMGTEK) framework, which has gained prominence in the Turkish national curriculum. In recent years, the intersection of engineering and entrepreneurship has been recognized as a driver for innovation (İrdem Ağrıman, 2022). For an engineer to be effective, they must not only design a product but also understand its value, feasibility, and impact on the community—traits synonymous with an entrepreneurial mindset. The integration of 3D design software (e.g., Tinkercad) and robotics (e.g., Arduino or LEGO sets) offers a modern context for this synergy (Moore et al, 2014). However, before evaluating the effectiveness of these high-tech tools, it is imperative to document the "conceptual baseline" of the students (Wendell & Lee, 2010). What are the driving components of the middle school students' engineering images? This study provides the foundational analysis required to answer such questions, filling a gap in the literature regarding how 5th graders in rural or developing urban areas of Turkey perceive the evolving nature of engineering.

The Intersection of Engineering and Entrepreneurship in Educational Frameworks

The evolution of 21st-century education has necessitated a shift from isolated disciplinary knowledge toward an integrated model that emphasizes innovation and value creation. Within this context, the "Science, Engineering, and Entrepreneurship" (FMGTEK) framework in the Turkish national curriculum represents a strategic effort to bridge the gap between technical design and economic literacy (MEB, 2024). This framework posits that engineering is not merely a technical endeavor but an entrepreneurial process where scientific principles are harnessed to meet societal and market needs.

A core component of this integration is the development of 21st-century skills, specifically creativity, critical thinking, and problem-solving within a real-world context. When students conceptualize engineering through lenses such as "participating in Teknofest" or creating a "suitable product for the customer," they are reflecting an awareness of the "entrepreneurial mindset". This mindset requires individuals to not only design a prototype but also to evaluate its feasibility and impact on the community. As noted in the literature, for an engineer to be effective in the modern era, they must possess the ability to recognize opportunities and navigate the complexities of product development—traits that are increasingly recognized as essential pedagogical outcomes (Deniz et al., 2020; İrdem Ağrıman, 2022).

Furthermore, the emphasis on competitions like Teknofest serves as a bridge between formal and informal learning environments, shaping how young learners perceive the ultimate goal of engineering. However, the challenge for educators lies in ensuring that these perceptions transcend the "competition" aspect and evolve into a systematic understanding of the Engineering Design Process (EDP). By anchoring engineering education in the FMGTEK framework, pedagogical interventions can foster a "conceptual baseline" where students view themselves as innovators capable of turning scientific inquiry into tangible social and economic value (McLean et al. 2020).

This study investigates students' perceptions of engineering not only through quantitative data but also through their "lived experiences" and the "subjective meanings" they assign to the field. A phenomenological approach centers on how a phenomenon—in this case, engineering—is experienced and defined by individuals. Fifth-grade students acquire fragmented information about engineering through the technological tools around them, school projects, or the media. The image of "engineering" formed by combining this information is part of their way of making sense of the world. The details students use in their drawings and their verbal expressions in interviews provide a mental map of this phenomenon.

Purpose and Originality of the Study

The overarching goal of this study is to provide a detailed qualitative map of the engineering conceptions held by 5th-grade students. By analyzing their interview responses and drawings, we aim to identify common themes, prevailing misconceptions, and the presence of stereotypical images. The significance of this work lies in its potential to inform curriculum developers and science teachers about the specific areas where student understanding is most limited. Furthermore, by documenting these perceptions, this research sets the stage for future longitudinal studies on conceptual change. In essence, this article argues that to build the engineers of the future, we must first understand the "engineers" currently residing in the imaginations of our children.

Methodology

This study employs a qualitative research paradigm to gain a deeper understanding of fifth-grade students' perceptions of engineering. Qualitative research is particularly effective in educational settings where the goal is to explore the complexity of human experience and conceptual development (Eberle, 2014). The research is structured as a phenomenological study. Phenomenology focuses on describing the common meaning for several individuals of their lived experiences of a concept or a phenomenon (Yıldırım & Şimşek, 2018). In this study, the "phenomenon" is the concept of engineering as perceived by middle school students before engaging in formal engineering design activities. This design allows the researcher to capture the essence of students' mental models and the subjective meanings they assign to being an engineer.

The study was conducted during the 2021-2022 academic year following the necessary official permissions gain from Tokat Gaziosmanpaşa University with 23.03.2021 dated and 25930 numbered and from the Tokat Provincial Directorate of National Education wit 07.10.2021 dated and E-27001677-44-34082813 numbered papers.

The sample selection conducting with purposive sampling. The participants consisted of 16 5th-grade students from a small district of Tokat, Turkey, 9 boys and 7 girls. A primary selection criterion was that participants had no prior experience with robotic coding, 3D design, or engineering-oriented extracurricular activities.

Semi-Structured Interviews: Students participated in interviews designed to elicit their verbal definitions of engineering. Questions focused on what an engineer does, where they work, and what tools they use. This format allowed students to express their thoughts freely while maintaining a focus on the core phenomenon.

Mental Images (Student Drawings): As a non-verbal tool, students were asked to draw an engineer at work. Drawing is a powerful method for revealing subconscious perceptions and stereotypes that might not be captured through verbal communication alone.

Student interviews were conducted face-to-face with each student, and audio recordings were made of the interviews. These interviews lasted approximately 10 minutes for each student. After the interviews all recording were typed to ready for analysis. Students were also given a piece of paper each and asked to draw engineering process picture, and they were given as much time as they needed to complete their drawings. The drawing process took between 15 and 30 minutes.

Data were subjected to content analysis. All interview recordings were reviewed and coded by the first author. To ensure reliability, the data were cross-coded by the second author, achieving an inter-coder agreement of 88.5% using the Miles and Huberman formula. Additionally, member check was conducted with the students after codes were crated to ensure whether codes presented reflects the participants' opinion.

Findings

During the interviews, all participants were asked the question, "What is engineering to you?" The analysis of the students' answers to this question is given in Table 1. Since the students' answers in the interviews corresponded to more than one code, the sum of the frequencies appears to be higher than the number of participants.

Table 1. Analysis of the interview related to the question "What is engineering to you?"

Codes	Frequencies
Doing architectural work	7
Doing electronic work	6
Profession	6
Desinging	5
Prototyping and testing	2
Success	1
Participating in Teknofest	1
Suitable product for the customer	1

As shown in Table 1, students provided varying levels of definitions of engineering in their interview responses. They mostly gave answers related to the professional work of engineers. In order of frequency, the answers given were related to architectural studies (f=7), electronic devices they produced (f=6), profession(f=6), and design work (f=5). Regarding engineering design processes, the answers given were prototyping and testing (f=2). Apart from these, a few students gave answers related to the individual characteristics of engineers and entrepreneurship. These answers were being successful (f=1) in the field of individual characteristics and participating in Teknofest (f=1) in the field of entrepreneurship.

Below are examples of student answers to the question "What is engineering to you?", along with the code snippets that served as reference points for each answer. Explanations of how these codes were generated are also provided below them.

P2: So, it's like architecture to me… Building pools, building houses. It's just like architecture… But there are robots too. (Codes: Doing architectural work and doing electronic work)

In response to the question, "What is engineering to you?", P2 answered that it means producing architectural works such as swimming pools and houses. Therefore, this student's answer was coded as "Doing architectural work." Furthermore, because of the phrase "there are robots too" at the end of the conversation, this student's opinion was evaluated under the code "Doing electronic work".

P8: For me, engineering is something I see both as a job and as a means of achieving success… We combine the two; it's something that unites both success and profession. (Codes: Success and Profession)

In response to the question, "What is engineering to you?", P8 answered by using the concepts of "job" and "success" together. Analysis of this answer suggests that Ayşe's use of the concept of "success" indicates her view that engineering is a matter of skill and achievement. Therefore, the code being successful is considered appropriate for this part of her answer to the question. Furthermore, in the other part of her answer, P8 stated, "It is something that combines both success and profession," indicating that engineering is a profession. Therefore, the code "profession" is considered appropriate for this part of her answer.

P3: I think engineering is about imagining things, experimenting with them on small things to test if they work, and finding the right things. Helping the country. Building various structures. Discovering various things. (Code: Prototyping and testing)

In response to the question, "What is engineering to you?" student P3 clearly described prototyping as experimenting on small things. She also used some other steps Engineering Design Process Skills such as idea generation, testing, and experimenting. These ideas were coded as prototyping and testing.

The question "In your opinion, how do engineers carry out the product development process?" was asked to gather information about the students' knowledge of engineering processes. Table 2 presents the analyses related to this question. Since the students' answers in the interviews corresponded to more than one code, the sum of the frequencies appears to be higher than the number of participants.

Table 2. Analysis of the interview related to the question "In your opinion, how do engineers carry out the product development process?"

Codes	Frequencies
Conducting tests and changing the product	12
Making a plan	10
Creating products	6
Measuring	5
Empathy	4
Designing	4
Making evaluation	4
Conducting research	3
Making a prototype	2
Working as a team	1

Table 2 shows that students answered the question "In your opinion, how do engineers carry out a product development process?" in the following order of frequency: they test and make changes to the product (f=12), they plan (f=10), they create the product (f=6), they measure (f=5), they empathize (f=4), they design (f=4), they receive evaluation (f=4), they conduct research (f=3), they make a prototype (f=2), and they work in a team (f=1). When the answers given to the questions were examined, conducting tests and changing the product was the most prominent answer regarding how engineers carry out their work. However, some of the engineering design steps were also seen in the students' answers. It was observed that students tried to define some of the engineering design processes, even if the definitions were not appropriate to the field content. For example, it was observed that they tried to define the empathy step as developing a product for a specific purpose, but this definition did not meet the human-centered definition of the empathy step. It was also observed that they evaluated the evaluation step as presenting it to the boss in terms of suitability for production.

Below are examples of student answers to the question "In your opinion, how do engineers carry out a product development process?", along with the code snippets that served as reference points for each answer. Explanations of how these codes were generated are also provided below them.

P5: Engineers conduct research, and based on this research, they create new things and present them to their bosses… we also consider the size of the thing being made, why it's being done, what our purpose is, for example, where we'll use it, then we design it, check if it worked, and look for any mistakes." (Codes: Conducting research and making evaluations)

When this response was analyzed, it was considered two themes stand out. Firstly, engineers conduct research, and secondly, they evaluate their products. The first part of the answer clearly states that engineers conduct research. Later, it was evaluated under the code of making evaluations with the phrases at the last part of the response.

P11: He does some research on the subject online. Then he watches some videos online. He doesn't do exactly what he learns from them, but he does something similar... He needs to do something that doesn't exist anywhere else in the world. (Code: Conducting research)

P11 responded with, "She researches some things on the internet" and "She watches some videos on the internet." Analyzing this response, it is clear that the student does research. Therefore, it was deemed appropriate to use the code conducting research.

The question "Who do you think can be an engineer?" was asked to students in an attempt to delve deeper into their knowledge of engineering. The analyses related to this question are presented in Table 3. Since the students' answers in the interviews corresponded to more than one code, the sum of the frequencies appears to be higher than the number of participants.

Table 3. Analysis of the interview related to the question, "Who do you think can be an engineer?"

Codes	Frequencies
Hardworking and determined	11
Intelligent	4
Expertise in the field	4
Self-confidence	4
Receive training for engineering	2
Good at science and math	2
Everyone	1

When the students' opinions in response to the question, "Who do you think can be an engineer?" were evaluated, as shown in Table 3, the most frequent answers were: hardworking and determined people (f=11), intelligent people (f=4), those with field expertise (f=4), people with self-confidence (f=4), those who have received engineering education (f=2), those who are good at science and mathematics (f=2), and everyone can be an engineer (f=1). An examination of the answers revealed that the opinions of students were clustered around personal characteristics, academic achievement, and field knowledge.

P9: Those who work hard. Engineering, for me, is... how can I put it? As a profession, it's very important... I don't think whether someone is male or female affects the choice of being an engineer. I also want to be an engineer." (Code: Hardworking and determined)

P9 student responded, "Those who work hard." Analyzing this response, it's understood that engineering is a profession requiring hard work and effort. Therefore, it was considered appropriate to use the code hardworking and determined for this answer.

P5: Intelligent people, sir. People with sharp minds. Not everyone can do it. People with self-confident. Because engineering is a difficult field. There's no gender discrimination, sir. I mean, both women and men can easily do engineering. (Codes: Intelligent, Self-confidence)

P5 responded to the question with the phrases "Intelligent people, sir. People with sharp minds," and "Confident people." Analyzing this, the answer "Intelligent people, sir. People with sharp minds" suggests that engineering is a difficult field, but only intelligent people can do it. Therefore, it was considered appropriate to use the code Intelligent for this answer. Similarly, it was considered appropriate to use the code Self-confident for the expression "People with self-confidence."

In order to gain a deeper understanding of students' perceptions of engineering processes, students were asked to draw pictures in response to the question, "Can you illustrate with a picture how engineers work when developing a product?". This was done to understand students' perceptions of the engineers' work process. Below are examples of student drawings illustrating how engineers work when developing a product illustrated at Figure 1 and Figure 2.

Figure 1. P2's drawing

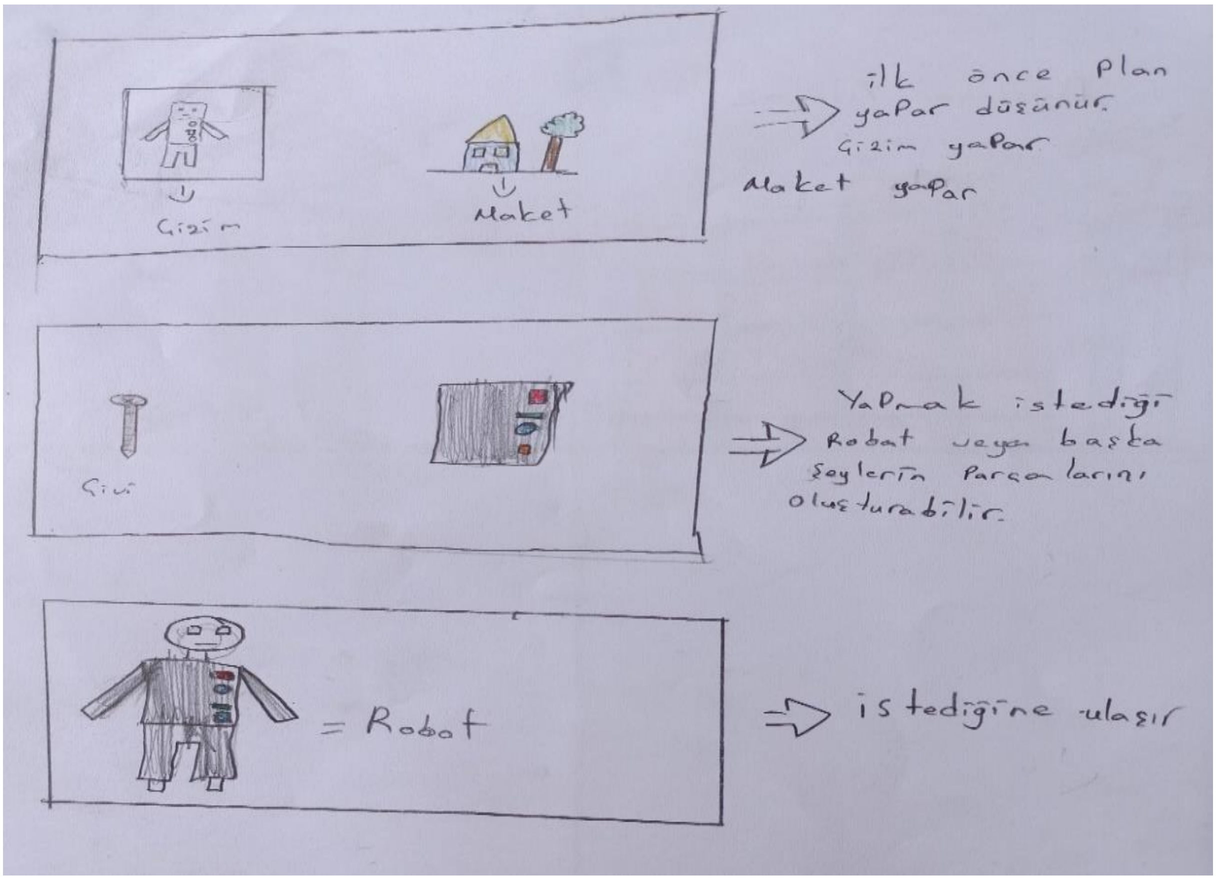

Figure 2. P14's drawing

The vast majority of students who participated in the study focused on the products that engineers produce while working in their drawings. Most students did not draw pictures related to engineering processes; only two students partially drew pictures related to engineering processes. The students' drawings, in order of frequency, depicted robots (f=8), construction (f=4), and cars (f=3). As an exception, some students drew some engineering processes (2). Below are examples of student drawings illustrating how engineers work when developing a product.

Discussion

This study aimed to examine students' views on engineering. The interviews revealed that students' responses regarding engineering mostly focused on producing electronic devices (robots and computers, etc.) and architectural work (bridges and buildings, etc.). However, only a small number of students provided answers regarding the testing and prototyping steps in the engineering design process. This situation was also observed in the analysis of the drawings of the engineering work process requested to examine the students' views on engineering in more depth. Except for two of the drawings, the students drew pictures of a man doing construction work, a robot, and an engineer working with a computer. Only two students showed some drawings that partially depicted presenting to the boss, testing, and correcting mistakes. Student interviews and engineering drawing projects ran parallel to each other, reflecting and supporting the students' engineering thinking.

Student interviews and engineering drawings revealed that students' engineering knowledge was centered around the perception of producing professional products. This situation was observed in the research results of Çakmak (2019), where students perceived engineering as invention and design. Based on the students' engineering drawing results, they found that the engineers perceived them as people working in construction and road building. His findings are consistent with the study. However, this shows parallels with the findings regarding students' perceptions of engineering encountered in the studies of Yıldırım and Türk (2018), Ergun and Balçın (2019), and Marulcu and Sungur (2012). The inadequacy of students' perceptions of engineering and related concepts may stem from their insufficient exposure to engineering applications within the curriculum. Guzey, Moore, and Harvel (2016) stated that a successful science and engineering education depends on high-quality activities and curriculum content related to the subject.

The findings of this research indicate that 5th-grade students' mental models of engineering are predominantly product-oriented and limited to visible physical structures. As evidenced by the high frequency of codes such as "architectural work" and "electronic work," students tend to view engineers as builders of houses or assemblers of robots rather than cognitive problem-solvers. This result is consistent with the international literature, which suggests that young learners often conflate engineering with manual labor or skilled trades (Çil & Özlen, 2019;, Ergün, 2018). A striking aspect of the data is the "technician-centric" view prevalent among participants. While some students identified "prototyping and testing" as part of the process, these were minority views compared to the perception of engineering as a final product. This conceptual narrowness may stem from a lack of exposure to the engineering design process (EDP) within the early years of the curriculum. In rural or developing urban contexts like the one studied here, students' primary sources of information appear to be traditional media and local environmental observations, which frequently depict engineers in hard hats at construction sites (Polat et al, 2020; Robinson et al., 2023). Furthermore, while students verbally expressed a lack of gender discrimination—stating that "everyone can be an engineer"—their drawings often depicted male figures in solitary roles. This "hidden stereotype" suggests that even when children possess the social vocabulary of equality, their subconscious visual models remain anchored in traditional archetypes ((Hammack et al., 2015; Moore et al., 2014).

The findings of this study should be interpreted within the specific socio-economic framework of the research site, a developing district in Tokat, Turkey. The students' tendency to define engineering through the lens of "construction" (f=4) and "manual labor" reflects the immediate industrial and agricultural landscape of their environment. In regions where large-scale high-tech laboratories are absent, children's mental models are naturally shaped by visible, tangible engineering—primarily civil engineering and machinery repair (Azodo, 2017; Malone et al., 2018). Furthermore, the participants' lack of prior exposure to robotic coding or 3D design software underscores a significant "digital divide". Their initial perceptions are not informed by contemporary STEM practices but are instead products of traditional societal stereotypes prevalent in disadvantaged areas. The dominance of the "builder" or "fixer" archetype in student drawings (e.g., P2's construction-focused drawing) suggests that in the absence of diverse technological role models, students default to localized, labor-intensive interpretations of the profession. This "conceptual baseline" highlights a critical pedagogical challenge: for students in socio-economically disadvantaged regions, the introduction of 3D design and robotics must be accompanied by a deliberate effort to deconstruct these localized stereotypes. Without bridging the gap between their "lifeworld" experiences and modern engineering processes, high-tech tools may remain alien to their career aspirations (Azodo, 2017; McLean et al., 2020). Therefore, this study argues that curriculum interventions in rural or developing areas must prioritize "contextualized engineering," which connects global design principles with the students' immediate socio-economic realities.

According to the findings of the study, following recommendations can be proposed to broaden to students' conception landscape:

- Teachers should implement "conceptual bridge" activities that link students' existing perceptions (e.g., building) to the cognitive aspects of engineering (e.g., empathy, optimization, and ethical decision-making).
- The "Science, Engineering, and Entrepreneurship" framework should be introduced not just through tools like 3D design and robotics, but through real-world problem-solving scenarios that emphasize the social impact of design.
- To dismantle the stereotypical "male-fixer" image, students should be exposed to diverse engineering professionals through guest speaker sessions or digital case studies that highlight the collaborative and digital nature of modern engineering.
- Rather than focusing solely on the final product, science education should explicitly teach the iterative nature of the Engineering Design Process, emphasizing that "failure" during testing is a critical step toward success.

Ethics Committee Approval

The study was conducted during the 2021-2022 academic year following the necessary official permissions gain from Tokat Gaziosmanpaşa University with 23.03.2021 dated and 25930 numbered and from the Tokat Provincial Directorate of National Education wit 07.10.2021 dated and E-27001677-44-34082813 numbered papers.

REFERENCES

Azodo, A. P. (2017). Attitude of engineering students towards engineering drawing: A case study. *International Journal of Research Studies in Education, 6*(1), 61–74.

Capobianco, B. M. (2011). Exploring a science teacher's uncertain identity as a teacher of engineering. *Journal of Science Teacher Education, 22*(3), 245-268.

Cunningham, C. M., Lachapelle, C., & Lindgren-Streicher, A. (2007*). Assessing elementary school students' conceptions of engineering and technology.* Portland, OR: American Societyof Engineering Education.

Çakmak, B. (2019). Analysis on perception of secondary school students on science and technology, engineering and mathematics (STEM). (Unpublished master's dissertation). Akdeniz University, Antalya.

Çil, E. & Özlen, S. (2019). Beşinci sınıf öğrencilerinin mühendis ve mühendislik algılarının incelenmesi. *Bolu Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, 19*(4), 1272- 1287.

Deniz, H., Kaya, E., Yesilyurt, E., & Trabia, M. (2020). The influence of an engineering design experience on elementary teachers' nature of engineering views. *International Journal of Technology and Design Education, 30*, 635-656.

Dobela, J., & Seboni, L. (2023). Attitudes and academic performance of engineering students in both prerequisite courses to final year project and final year project. *International Journal of Higher Education, 12*(1), 1-45.

Eberle, T. S. (2014). *Phenomenology as a research method.* In Flick U. (Ed.), The SAGE handbook of qualitative data analysis (pp. 184-202). Sage Publications.

Ergün, A. (2018). Türk ortaokul öğrencilerinin mühendislik ve teknoloji algıları: Sınıf düzeyi ve cinsiyetin etkisi. *International Journal of Human Sciences, 15*(4), 2657- 2673.

Ergun, A. & Balcin, M. D. (2019). The perception of engineers by middle school students through drawings. *Eurasian Journal of Educational Research, 19*(83), 1-28.

İrdem Ağrıman, N. (2022*). Investigation of science teachers' nature of engineering views.* (Unpublsihed master thesis). Middle East Technical University, Ankara.

Guzey, S. S., Moore, T. J. & Harwel, M. (2016). Building up stem: An analysis of teacher-developed engineering, *Journal of Pre-College Engineering Education Research, 6*(1), 11-29.

Hammack, R., Ivey, T.A. & Utley, J. (2015). Effect of an engineering camp on students' perceptions of engineering and technology. *Journal of Pre- College Engineering Education Research, 5*(2), 1-12.

Malone, K. M., Tiarani, V., Irving, K. E., Kajfez, R., Lin, H., Giasi, T. & Edmiston, B. W. (2018). Engineering design challenges in early childhood education: effects on student cognition and interest. *European Journal of STEM Education, 3*(3),1-18.

Marulcu, İ. & Sungur, K. (2012). Fen bilgisi öğretmen adaylarının mühendis ve mühendislik algılarının ve yöntem olarak mühendislik-dizayna bakış açılarının incelenmesi. *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 12*(1), 13-23.

McLean, M., Nation, J. M. & Spina, A. (2020). The importance of collaborative design for narrowing the gender gap in engineering: An analysis of engineering identity development in elementary students*. Journal of Pre-College Engineering Education Research, 10*(2), 17- 34.

Millî Eğitim Bakanlığı [MEB]. (2024). Fen Bilimleri Dersi Öğretim Programı (ilkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. sınıflar). Ankara: MEB Talim ve Terbiye Kurulu Başkanlığı. https://mufredat.meb.gov.tr/

Mohammadi-Aragh, M. J., Kajfez, R. L., Clark, A., & Sassi, S. (2025). Engineering identity formation across the undergraduate years. *International Journal of Engineering Education, 41*(6), 1616–1630.

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., & Roehrig, G. H. (2014). Implementation and Integration of Engineering in K-12 STEM Education. J. Strobel, S. Purzer, & M. Cardella (Eds.), *In*

Engineering in precollege settings: Research into practice, (pp. 35-60). Rotterdam, the Netherlands: Sense Publishers.

Opara, L. U., Al-Adawi, S. S., & Al-Shukeili, T. S. (2006). Student perceptions of the public image of agricultural engineering and their preferred name for the discipline and title degree. *International Journal of Engineering Education, 22*(1), 59-66.

Piaget, J. (1929). *The child's conception of the world.* Harcourt, Brace.

Polat, S., Yanmaz, O., & Kadaifci, C. (2020). Birinci sınıf öğrencilerinin endüstri mühendisliği mesleğine yönelik algıları. *Yükseköğretim ve Bilim Dergisi, 10*(3), 429-437.

Robinson, T., Kirn, A., Amos, J., & Chatterjee, I. (2023). The effects of engineering summer camps on middle and high school students' engineering interest and identity formation: A multi-methods study. *Journal of Pre-College Engineering Education Research, 13*(2), 82-106.

Tytler, R. (2020). *STEM education for the twenty-first century*. In J. Anderson & Y. Li (Eds.), Integrated approaches to STEM education (pp. 21–43). Springer.

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology, 24*(4), 535-585.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press.

Wendell, K. B., & Lee, H. S. (2010). Elementary students' learning of materials science practices through instruction based on engineering design tasks. *Journal of Science Education and Technology, 19*(6), 580-601.

Xu, T., & Jack, L. (2023). Engineers in young children's minds: An exploratory case study of young children's drawings and narratives. *Early Childhood Education Journal, 52*(2), 1–8

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

Yıldırım, B. & Türk, C. (2018). STEM uygulamalarının kız öğrencilerin STEM tutum ve mühendislik algılarına etkisi. *Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, (30)*, 842-884.