Visual Complexity Analysis of Mimar Kemalettin's Educational Buildings

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The First National Architecture Period emerged during the transition from the Ottoman Empire to the Republic of Turkey, a period marked by the intensification of the search for national identity, which significantly affected the field of architecture. The architectural understanding of this period stands out especially in the facade designs of public buildings. Mimar Kemalettin is recognised as one of the leading figures of this movement, which synthesised Seljuk and Classical Ottoman architectural elements with Neo-Classical design principles. This study aims to analyze, through a comparative approach, the similarities and differences in the facade designs of eighteen educational buildings attributed to Mimar Kemalettin, some of which were constructed, while others remained at the design stage. The average visual complexity of the facade drawings was calculated using the fractal analysis method. In this research, educational buildings are divided into three categories, namely primary schools, madrasas, and higher education institutions. The results were evaluated chronologically and comparatively according to these three categories. When the average visual complexity of educational buildings is examined chronologically, no linear change is observed. However, there is a tendency for complexity to increase over time in higher education institutions and madrasas, while a decreasing trend is evident in primary schools. This indicates that the architect's design approach varied over time according to the educational building's category. When the average visual complexity of educational buildings is compared categorically, primary schools and madrasas are found to exhibit "similar" characteristics. In contrast, madrasas and higher education institutions display "dissimilar" qualities, and likewise, "dissimilar" features are also identified between primary schools and higher education institutions. It was also observed that educational buildings in the higher education institution category exhibit more complex facade characteristics. In conclusion, these findings indicate that Mimar Kemalettin adopted a design approach that varied according to educational level.

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Mimar Kemalettin'in Eğitim Yapılarının Görsel Karmaşıklık Analizi

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Birinci Ulusal Mimarlık Dönemi, Osmanlı İmparatorluğu'ndan Türkiye Cumhuriyeti'ne geçiş sürecinde, mimarlık alanını önemli ölçüde etkileyen ulusal kimlik arayışlarının yoğunlaştığı bir dönemde ortaya çıkmıştır. Bu dönemin mimari anlayışı, özellikle kamu yapılarının cephe tasarımlarında öne çıkmaktadır. Mimar Kemalettin, Selçuklu ve Klasik Osmanlı mimari unsurlarını Neo-Klasik tasarım ilkeleriyle sentezleyen bu hareketin önde gelen isimlerinden biri olarak tanınmaktadır. Bu çalışma, Mimar Kemalettin'e atfedilen, hem inşa edilmiş hem de tasarım aşamasında kalmış, on sekiz eğitim yapısının cephe tasarımlarındaki benzerlikler ve farklılıkları karşılaştırmalı bir yaklaşımla analiz etmeyi amaçlamaktadır. Cephe çizimlerinin ortalama görsel karmaşıklık değerleri fraktal analiz yöntemi uygulanarak hesaplanmıştır. Eğitim yapıları, ilkokullar, medreseler ve yüksek eğitim kurumları olmak üzere üç kategoriye ayrılmıştır. Bulgular kronolojik olarak ve kategorik olarak karşılaştırmalı olarak değerlendirilmiştir. Eğitim yapılarının ortalama görsel karmaşıklık değerleri kronolojik olarak incelendiğinde, doğrusal bir değişim gözlemlenmemektedir. Ancak, yüksek eğitim kurumu ve medreselerde karmaşıklığın zamanla arttığı, ilkokullarda ise azaldığı yönünde bir eğilim dikkat çekmektedir. Bu durum, mimarın zaman içindeki tasarım yaklaşımının eğitim yapısının kategorisine bağlı olarak farklılaştığını göstermektedir. Eğitim yapılarının ortalama görsel karmaşıklık değerleri kategorik olarak karşılaştırıldığında, ilkokullar ile medreselerin "benzer" özellikler gösterdiği tespit edilmiştir. Medreseler ile yüksek eğitim kurumu yapılarının "farklı" nitelikler sergilediği görülürken, ilkokullar ile yüksek eğitim kurumu yapıları arasında "farklı" özelliklerin bulunduğu tespit edilmiştir. Ayrıca yüksek eğitim kurumu kategorisindeki eğitim yapılarının daha karmaşık cephe özellikleri sergilediği gözlenmiştir. Sonuç olarak, bu bulgular Mimar Kemalettin'in eğitim kademesine göre farklılaşan bir tasarım yaklaşımı benimsediğini göstermektedir.

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1. INTRODUCTION

The emergence of the First National Architecture Period dates back to a transformative period marked by significant social, cultural, and architectural changes during the transition from the Ottoman Empire to the Republic of Turkey. The globally reverberating effects of nationalism, modernisation efforts, and nation-building triggered a new architectural movement, the First National Architecture Period (Bozdoğan, 2008). This period, which lasted from 1908 to 1930, was perceived as a means of expressing national identity (Sözen, 1984). The characteristics of this period were clearly emphasised in the facade designs of public buildings (Hasol, 2017). Mongeri's quote, "Let us see the facades, not the plans," is shown as the primary source of this point of view (Ünsal, 1973).

Mimar Kemalettin was one of the leading figures of the First National Architecture Period and stood out with his "public architect" identity (Tanyeli, 2007). He was influential in the design of many public buildings of different typologies, including educational buildings. In the literature, there are studies analysing the buildings of the First National Architecture Period (Ekinci, 2015; Sıkıçakar, 1991). However, studies on Mimar Kemalettin and educational buildings focus on documentation and conservation concerns (Koçak, 2023; Yavuz, 2009; Yazar & Kishalı, 2019; Yazıcı Metin et al., 2023).

In contemporary architectural research, evaluating historical buildings through measurable methods provides an analytical contribution to the field. In this context, fractal analysis is a significant method for quantifying visual complexity and comparing different facade compositions. In the literature, studies such as Ediz and Ostwald's research on the Süleymaniye Mosque (Ediz & Ostwald, 2012), Kuruçay's examination of thirteen mosques designed by Mimar Sinan (Kuruçay, 2020), Kanatlar's analysis of Sedad Hakkı Eldem's professional periods through selected residential works (Kanatlar, 2012), Erkan and Haştemoğlu's study of the Berlin–Baghdad railway stations (Erkan & Haştemoğlu, 2015), and Wen et al.'s analysis of the residential plans of Wright, Le Corbusier, and Mies van der Rohe (Wen & Kao, 2005) demonstrate that fractal analysis has been widely applied in the comparative evaluation of architectural works across different periods, geographies, and scales.

A review of the literature further reveals that studies on the First National Architectural Period primarily focus on the typological and image analyses of public buildings. However, research on the educational buildings of this period has largely been confined to documentation and description, while mathematical analyses of the facade compositions are quite rare. Quantitatively examining the visual complexity of the facades of educational buildings is crucial for a more comprehensive understanding of the architectural approach of the period. Nevertheless, a study analysing the facade designs of educational buildings designed during this period using fractal analysis methods has not been conducted. This gap underscores both the originality and the significance of the present study.

Using fractal analysis methods, this study aims to evaluate the similarities in the average visual complexity values on the facades of primary schools, madrasas, and higher education institutions known to have been designed by Mimar Kemalettin. The aim is to compare the visual complexity values of educational buildings. Within the scope of the study, forty-eight facade drawings belonging to a total of eighteen buildings by Mimar Kemalettin, either constructed or remaining at the design stage, were examined. Among these, eight remained at the design stage, while ten were realized. The facades of these buildings were categorized and analyzed. In this study, the fractal analysis method, as one of the morphological analysis approaches, was employed to quantitatively reveal the similarities and differences in the facade composition and organization of Mimar Kemalettin's educational buildings. The evaluations demonstrated the changes and variations observed in these buildings. Furthermore, the study holds significance as it provides a basis for comparing the fractal values of cultural heritage buildings at different scales within the framework of physical and socio-cultural norms.

2. BACKGROUND TO THE RESEARCH

This section begins by summarising key changes in the education system during the First National Architectural Period. It then examines the life and educational structure of Mimar Kemalettin. During the modernization period, educational developments primarily began at the military and higher education levels (Tekeli, 2011). The societal changes during the Second Constitutional Era accelerated the reform

of the education system. While sultani, idadi, military, and civil rüşdiye schools were opened at the secondary level, mekteb-i ibtidai schools became institutions offering modern education at the primary level. Traditional institutions like sıbyan schools and madrasas were also subject to curricular modernization. However, this led to a division of educational institutions into three categories before the Republic: madrasas, Tanzimat schools, and foreign schools. According to Ziya Gökalp's sociology of education, this division is reflected in society as three different groups: sofi, Levantine, and Tanzimatist (Celkan, 1977). With the proclamation of the Law on the Unification of Education (Tevhid-i Tedrisat) in 1924, madrasas were closed, and all educational institutions were placed under the Ministry of National Education, thereby ensuring educational unity (Parmaksızoğlu, 1948).

2.1 Mimar Kemalettin and Educational Buildings

Mimar Kemalettin (1870-1927) was a Turkish architect who witnessed many significant events during his lifetime. His architectural career began in 1887 when he enrolled at the Hendese-i Mülkiye (Yavuz, 1981a). At this institution, he developed an interest in drawing and architecture and received training from experts such as Professor Jasmund (Çetintaş, 1944). It is known that he assisted Jasmund in the Sirkeci Station project (Çetintaş, 1944; Yavuz, 2015). In 1891, Kemalettin Bey was appointed as Professor Jasmund's assistant at Hendese-i Mülkiye Mektebi and taught design courses for four years, during which he also established his private office (Gövsa, 1946). His early designs reflect eclectic styles. In 1895, he was sent to Berlin to specialize as the Ottoman state architect (Doğuoğlu Fındıkgil, 2009). After completing a two-year higher education program at Charlottenburg Technische Hochschule, he worked in Germany for about two and a half years (Yavuz, 1981a). Between 1909 and 1919, the expansion of the powers of the Construction and Restoration Technical Committee of the Ministry of Foundations (Evkaf Nezareti) enabled the reflection of the national architectural idea in new public buildings. During this period, Mimar Kemalettin became a highly active figure in construction (Yavuz, 1981b).

Archival documents and period practices indicate that Kemalettin Bey, as the Chief Architect of the Ministry of Foundations, played an influential role in the design of educational buildings during his tenure (Yavuz, 2009). Furthermore, since the Ministry of Foundations

functioned like an architectural school during this period, names such as Mimar Nihat and Ali Talat are also mentioned in relation to certain projects (Batur & Cephanecigil, 2009). A total of eighteen educational buildings attributed to Mimar Kemalettin - some of which were constructed, while others remained at the planning stage - are examined in this study. These buildings are dated between 1909 and 1927. These buildings are mainly located in Istanbul. However, there are educational building designs in Ankara, Medina, and Edirne (Yavuz, 2009). The educational buildings designed by Mimar Kemalettin can be categorised under three headings: primary education institutions, madrasas, and higher education institutions (Köksalan & Şahin, 2024). The characteristic features of the facades of these educational buildings include varying window forms on different floors and continuous string courses that follow the lines of the windows. A prominent projection typically accentuates the front facade. Tiled hipped roofs are also a common feature **(Table 1)**.

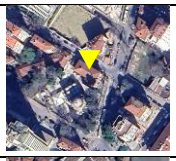
School	Year and Location		Photograph	
Reşadiye Primary School	İstanbul, 1910			(Demirtaş & Uysal, 2012)
Fethiye Madrasa	İstanbul, 1909-1919			(Fethiye Medresesi, 2019)
Bostancı Primary School	İstanbul, 1913-1914			(Kültür Envanteri, 2023)
Medreset'ül Kuzat	İstanbul, 1913			(Medreset ü'l-Kuzât, n.d.)
Ayazma Primary School	İstanbul, 1913-1917			(Ayazma Mektebi, 2022)

Table 1: Table showing locations and photographs of constructed schools

Göztepe Primary School	İstanbul, 1914			(Kültür Envanteri, 2021)
Abdülhamid-i Evvel Madrasa	İstanbul, 1912-1915			(Yavuz, 2009)
Madrasa in Medina	Medina, 1914-1915			(Dar Al-Qalam, 2020)
Mimar Kemal Primary School	Ankara, 1926-1927			(Köksalan, 2024a)
Gazi Education Institute	Ankara, 1927-			(Köksalan, 2024b)

Reşadiye Primary School **(Figure 1a)** is Mimar Kemalettin's first educational building design. Its facade composition is distinguished by its octagonal plan and the onion-domed prayer room section. (Yazar & Kishalı, 2019). Just above the flat-arched entrance door, there is a crescent and star motif. Square-framed geometric reliefs, panels, and penci-arched[1] windows are among the facade ornaments (Demirtaş & Uysal, 2012). The front facades of the Bostancı **(Figure 1c),** Ayazma **(Figure 1d)**, and Göztepe **(Figure 1f)** primary schools are highlighted by a protruding main entrance (Yavuz, 2009). However, the side and rear facades differ in similarity. In the "School for the Deaf and Blind"[2] **(Figure 1b)**, pointed arches are used on the ground floor, while rectangular windows are found on the first floor. Entrances are provided from side axes, and the arched, stair-accessed entrances are topped with balconies. The masses that protrude from the front facade and vary in height give the structure a dynamic appearance. Both the "Six-classroom school" **(Figure 1g)** and the Karaağaç Primary School

[1] A term for the five-centered arches common in the period.
[2] This project is referred to as "School for the Deaf and Blind" in the text and is indicated as "Dilsiz ve Âmâlara Mahsus Mektep" in the archives.

(Figure 1e) were designed with an "I" plan layout. The "Six-Classroom School" is a two-story building, whereas the Karaağaç Primary School is a single-story structure featuring wide, penci-arched windows (Yavuz, 2009). The primary school design in İstinye (Figure 1h) stands out with its tower-like mass. In the design of Fünun-u Cedid Primary School (Figure 1i), various sizes and shapes of twin windows, penci-arched, and flat-arched window forms were used. The Mimar Kemal Primary School (Figure 1j) is the only primary school designed during the Republican period. It includes window string courses and has a more modest appearance compared to the other primary school buildings.

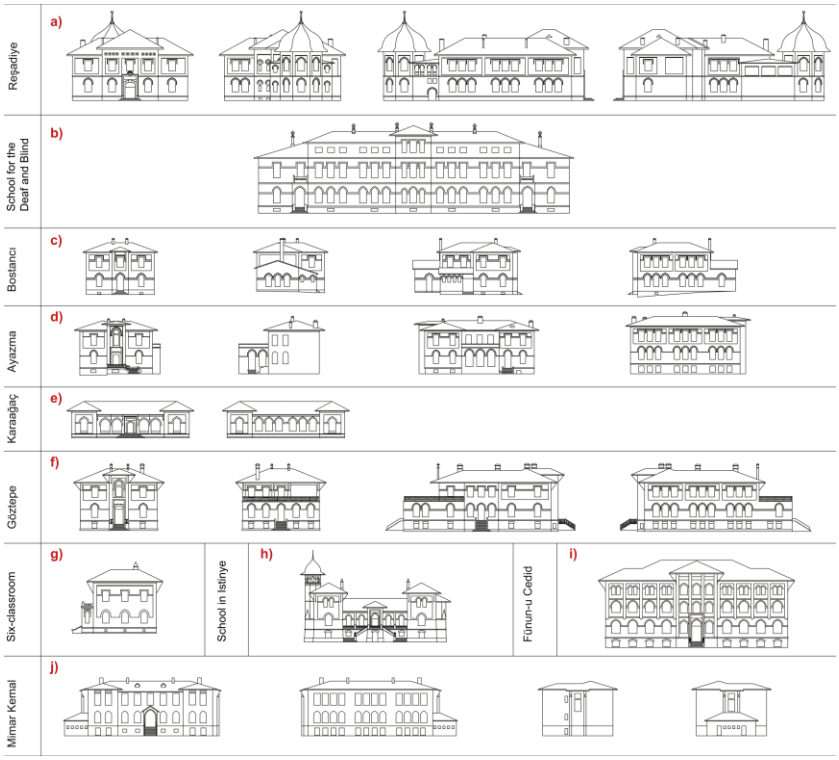


Figure 1: Primary Schools
a) Reşadiye (Demirtaş & Uysal, 2012),
b) School for the Deaf and Blind (Batur & Cephanecigil, 2009),
c) Bostancı (MEB Arşivi, 2013),
d) Ayazma (MEB Arşivi, 2014),
e) Karaağaç (Yavuz, 2009),
f) Göztepe (Yamaner, 2019; Yavuz, 2009)
g) Six-classroom school (Yavuz, 2009),
h) School in İstinye (Yavuz, 2009),
i) Fünun-u Cedid (Batur & Cephanecigil, 2009),
j) Mimar Kemal (Yıldız, 2014)

Fethiye Madrasa (Figure 2a) and Hasanzade Madrasa (Figure 2b) are among the architect's early madrasa designs. For this reason, traces of the old-style madrasa design can be seen in their plan designs (Ahunbay, 1999). In the facade designs, window forms and ornamentation features characteristic of the period are seen (Yavuz, 2009). Medresetü'l-Kuzât (Figure 2c) symbolises the shift from madrasa education to modern education (Yavuz, 1981b). On the front facade, there is a double-winged entrance door with penci arches and windows on the sides. The upper part is decorated with calligraphic plates and rosettes. Mouldings, panels, and inverted tassel decorations following

the window form enrich the facade. While the vertical plaster-like elements continue to the ground-floor moulding, the rear facade is kept simpler. It can be said that Abdülhamid-i Evvel Madrasa **(Figure 2d)** represents an innovative approach to the classical madrasa typology (Batur, 2008). The ground floor has arched windows, while the upper floor has flat lintel windows. Continuous mouldings, plasterwork, and carved rosettes adorn the facade. There are penci-arched windows on the ground floor and flat lintel windows on the upper floor. Continuous mouldings, plasters, and carved rosettes decorate the facade. Madrasa in Medina **(Figure 2e)** has basement windows with flat arches, ground-floor windows with penci arches, and first-floor windows with rectangular forms. The main entrance axis is emphasised by increasing the height of the rectangular windows in this section by protruding above the eaves level. There are significant differences between design and construction.

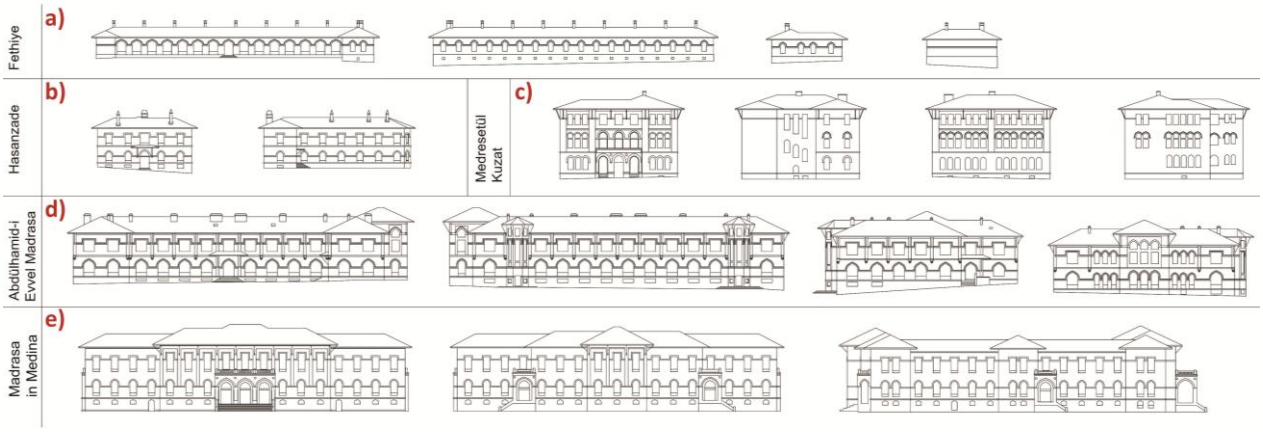


Figure 2: Madrasa Facades
a) Fethiye (MEB Arşivi, 2012),
b) Hasanzade (Batur & Cephanecigil, 2009),
c) Medresetül Kuzat (Temelli, 2004),
d) Abdülhamid-i Evvel (YİKOB Arşivi, 2012),
e) Madrasa in Medina (Yavuz, 2009)

The project for the Dârü'l-Muallimat (School for Female Teachers) **(Figure 3b)** remained in the design phase. In the facade design, penci-arched windows of different sizes and shapes are used. The facade is emphasised by projection and overhang above the eaves level. There are mouldings and panels surrounding the windows. There are inverted tassel-like ornamental elements at the ends of the plaster-shaped vertical elements. Corner towers are a remarkable feature of the design. Gedikpaşa Mekteb-i Alisi **(Figure 3c)** also remained in the design phase. Tower-shaped elements, covered with small-scale domes that overhang at the eaves, create a rhythmic appearance. Window forms included depressed, pointed, flat, and Bursa-arched windows (Arslan Çinko, 2020). Continuous mouldings following the window form are

seen on the ground floor. On the facade of Gazi Education Institute (Figure 3a), a semi-open area in front of the entrance features a portico with marble columns (Duru, 2024; Yavuz, 2009). On the upper floor, this section becomes a covered balcony, and on the third floor, it becomes an open terrace. In the Gazi Education Institute, Turkish triangle-shaped column capitals are used on the rear facade, and muqarnas column capitals are used on the front facade.

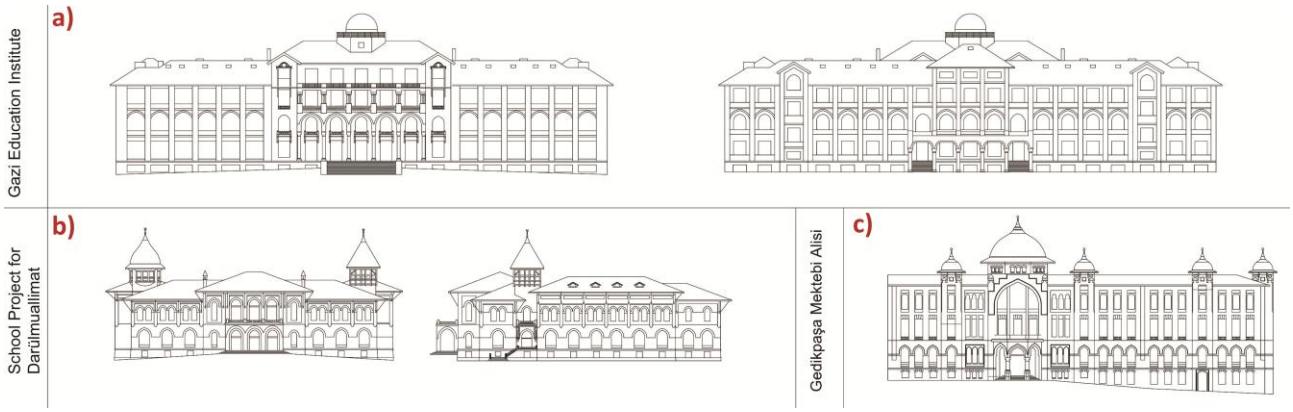


Figure 3: Facades of Higher Education
a) Gazi Education Institute (Duru, 2024)
b) School for Darülmuallimat (SALT Research, n.d.),
c) Gedikpaşa Mekteb-i Alisi (Yavuz, 2009)

3. METHOD: FRACTAL ANALYSIS

This study employs the fractal analysis method to calculate the complexity dimensions of facade compositions in educational buildings designed by Mimar Kemalettin. Phase 1 involved a literature review, while Phase 2 examined 18 of his educational buildings using archival and written sources. In Phase 3, facade drawings were prepared in CAD and analyzed with FracLac. Phase 4 focused on obtaining, classifying, and discussing the findings. Finally, Phase 5 summarized the results, highlighted contributions, and the findings were then compared and evaluated (Figure 4).

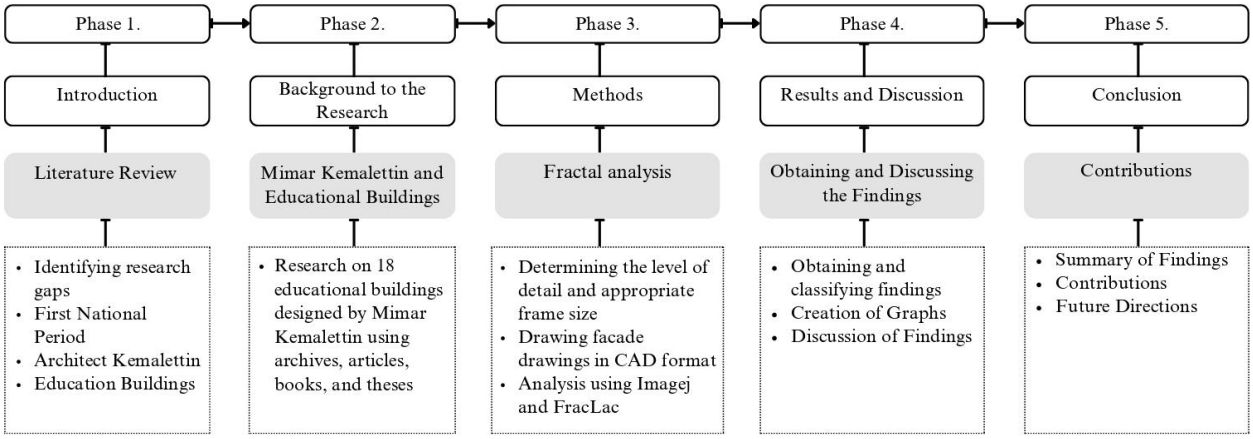


Figure 4: Research workflow

The calculation of fractal geometry and fractal dimension is based on Mandelbrot's work, questioning roughness (Mandelbrot, 1982). Fractal dimension and fractal geometry are two complementary yet distinct concepts. Fractal geometry refers to the complex forms produced by the self-similarity and repetition of objects of different scales. Numerical values that can be calculated to compare the similarity of forms are called the fractal dimension (Barnsley, 2014; Bovill, 1996).

It is well known that complex and contradictory elements often come together in architecture (Venturi, 2023). In this respect, Bovill's study is an important reference for discussing fractals and complexity within the same architectural context (Bovill, 1996). The fractal analysis method enables the mathematical evaluation of the visual complexity of architectural structures. Research in the literature shows that fractal analysis focuses on building examples of a period, an architect, or an architectural movement. In the literature, studies examine the intuitive use of fractal constructions in historical buildings (Ediz & Çağdaş, 2005; Ediz & Ostwald, 2012). Many studies use fractal analysis to measure visual complexity. These studies often question the connections between different historical design approaches and the similarities in architectural facades and plans (Lionar & Ediz, 2020; J. L. Vaughan, 2017). In addition, there are also studies that aim to question architects' search for design over the years in chronological order (Dawes et al., 2023; Kanatlar, 2012; Kuruçay & Ediz, 2025; M. Ostwald et al., 2008; J. Vaughan & Ostwald, 2022).

The box-counting method is one of the most common techniques for calculating the fractal dimension, which quantifies the richness of repetition and detail in two-dimensional objects or textures. This method allows the calculation of the complexity of facade and plan design in architecture (M. J. Ostwald & Vaughan, 2016). This method can be used to understand the degree to which a design has multi-level detail, but it does not provide information about design quality and aesthetic values (M. Ostwald & Tucker, 2007). The numerical values range between 1 and 2 and are expressed by the fractal dimension (D) (Mandelbrot, 1982). The reason for this is that fractals are not expressed as integers, unlike Euclidean geometry. Increasing the fractal dimension indicates greater complexity, while decreasing it indicates less complexity (Torrens & Alberti, 2000). When applying the box-counting method, the level of detail in the object's representation affects the results. The level of detail was examined in five layers in Ostwald and Vaughan's study (M. J. Ostwald & Vaughan, 2016).

4. RESULTS AND DISCUSSION

Within the scope of the research, forty-eight facade drawings from eighteen buildings were evaluated. The fractal analysis method allows for comparative evaluation of the formal properties of the facades by converting them into digital data. The fractal dimensions of the examined facades were obtained using the FracLac plugin of ImageJ software (Zarnowiecka, 1998). The "Grid Design" section enables the selection of the grid method to be used in the analysis of the image, as well as the determination of the number of subdivisions in the horizontal and vertical directions and the scale. The "Multifractal Options" section is employed for conducting fractal dimension analyses on multiple files. The "Graphics Options" section is used to organize results, while the "Files" section provides settings for saving the outputs of analyses (Şahin et al., 2025).

When fractal dimension calculations were performed, elevation drawings were prepared in AutoCAD 2021 based on reference sources, at the outline + primary form representation level. The size of the rectangular frame of the drawings prepared for analysis was scaled using the ratio 1.41421 (√2), and the drawing was positioned in the center (Lionar, 2021). Fractal analysis data were obtained using ImageJ. Within the scope of the study, in the grid design section, the grid

position was set to 12, as suggested by the FracLac plugin. Since the aim is to perform a detailed fractal analysis and examine a mathematical relationship, “Power Series” was chosen as the scaling method. Regression was selected in the graphic options section, data details were determined in the files section, and analysis data were obtained **(Figure 5).**

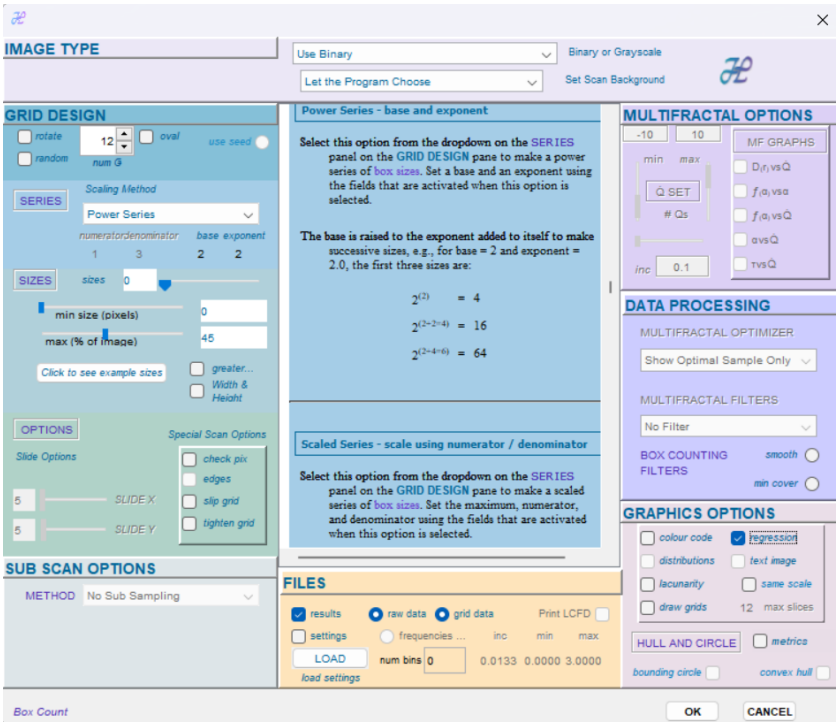


Figure 5: Interface View of the FracLac Plugin in Image-J Software

While evaluating the findings, visual complexity values closest to 1 are defined as “lowest visual complexity” and values closest to 2 are defined as “highest visual complexity”. Since the fractal dimension value will vary depending on the level of detail of the drawing, the comparison was made by considering the percentage difference in fractal dimension values (Kuruçay, 2020). In the study, the similarity between the fractal dimension values obtained as a result of the analyses was evaluated with reference to the table below **(Table 2)**.

Fractal Dimension Difference%	Similarity status
%0 to %1	very similar
%1 to %4	similar
greater than 4%	dissimilar

Table 2: Fractal dimension parameters (Lionar, 2021)

The fractal dimension values for eighteen designs, both completed and those remaining in the design phase, were found as shown in the table below. The findings were evaluated using the average fractal dimension values (D) as a reference. Educational structures were examined under three headings based on their education levels: primary education, madrasas, and higher education institutions (Table 3).

Table 3: Complexity values of educational buildings (created by author)

Category	Date	Name	Front Elevation	Rear Elevation	Right Elevation	Left Elevation	D (ort)[3]
Primary School	1910	Reşadiye	1.31	1.32	1.34	1.36	1.33
	1910	School for the Deaf and Blind	1.37	-	-	-	1.37
	1912	Bostancı	1.29	1.22	1.28	1.28	1.26
	1913-1917	Ayazma	1.30	1.20	1.33	1.33	1.29
	1909-1919	Karaağaç	1.35	1.23	-	-	1.29
	1914	Göztepe	1.29	1.34	1.38	1.38	1.34
	-	Fünun-u Cedid	1.38	-	-	-	1.38
	-	Six-classroom school	-	-	1.24	-	1.24
	-	School in İstinye	1.30	-	-	-	1.30
	1926-1927	Mimar Kemal	1.28	1.23	1.19	1.16	1.21
Madrasa	1909-1919	Fethiye	1.31	1.31	1.16	1.20	1.24
	1912	Hasanzade	1.19	-	-	-	1.25
	1913	Medresetü'l-Kuzât	1.31	1.22	1.32	1.25	1,27
	1912-1915	Abdülhamid-i Evvel	1.47	1.47	1.40	1.38	1,43
	1914-1915	Madrasa in Medina	1.41	1.36	-	1.40	1,39
Higher Education	-	School project for the Dârü'l-Muallimât	1.38	-	1.42	-	1,40
	1911-1912	Gedikpaşa Mekteb-i Alisi	1.48	-	-	-	1,48
	1927-1930	Gazi Education Institute	1.43	1.53	-	-	1,48

It is known that ten of the evaluated educational buildings have been constructed, and eight are in the design phase. According to this data, when educational buildings are evaluated according to their construction status, the average fractal dimension value in the constructed structures is 1.32. It was observed that the average fractal dimension values in the educational buildings remaining in the design phase were 1.33. The relationship between the visual complexity of buildings that remained in the design phase and those that were built was determined to be "very similar" (Figure 6).

[3] D (ort): average fractal dimension value, the arithmetic mean of the elevations of the Front, Rear, Right and Left elevations. Data for which facade drawings were not available are indicated with a minus sign (-) in the table.

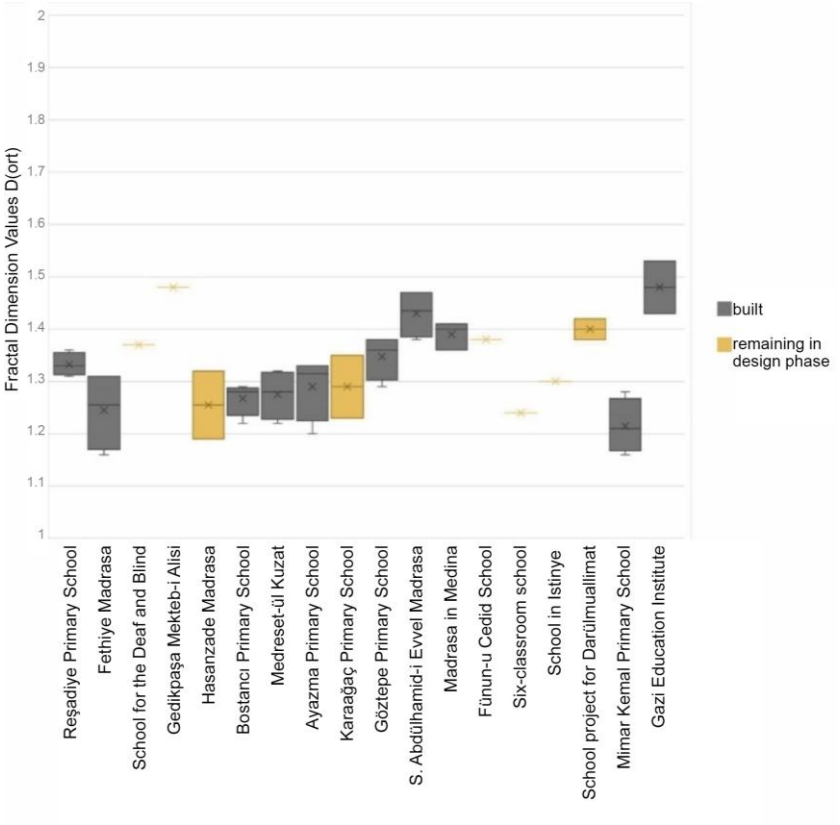


Figure 6: Comparison of fractal dimension averages of educational buildings (built: grey, remaining in design phase: yellow) (created by author)

When considered chronologically, educational buildings were examined in two separate periods: 1909-1919 and the post-1925 era, due to uncertainty surrounding the dates of some designs **(Figure 6).** The average fractal dimension values of eighteen designs display a fluctuating pattern over time. Although no clear linear continuity is observed, a slight upward tendency emerges in the overall trend. This indicates that the architect's approach to facades did not undergo a radical transformation solely over time. On the other hand, categorical differences are more evident. Higher education institutions and madrasas show an increasing tendency toward visual complexity, whereas primary schools show a declining trend. Thus, it can be concluded that the architect's design approach over the years varied primarily in relation to the category of the educational building.

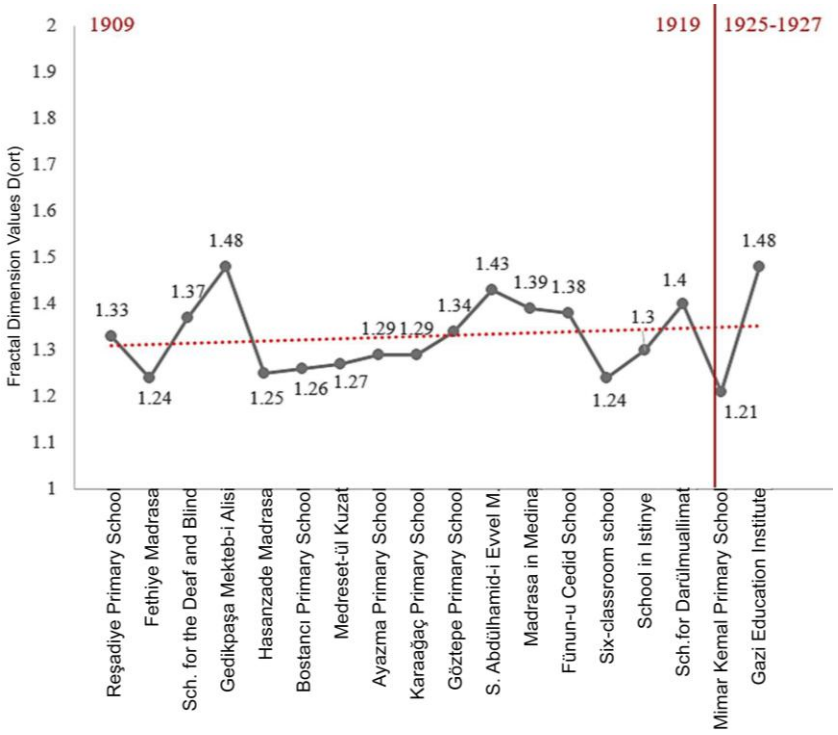


Figure 7: Chart showing the fractal dimensions of educational structures in chronological order (created by author)

When the designs at the primary school level were evaluated, the buildings with the highest average fractal dimension value were determined as Fünun-u Cedid School (D=1.38) and School for the Deaf and Blind (D=1.37). The fact that Fünun-u Cedid School is a large-scale, multi-storey design and has more window openings on its facade than other primary schools is reflected in the visual complexity value. When the average fractal dimension values are compared between Göztepe, Bostancı, and Ayazma Schools, which are stated to have similar characteristics in the literature, the percentage difference between Bostancı (D=1.26) and Ayazma Schools (D=1.29) is in the “similar” category with 2.38%. The percentage difference between Ayazma (D=1.29) and Göztepe Schools (D=1.34) is in the “similar” category with 3.88%, and the percentage difference between Bostancı (D=1.26) and Göztepe (D=1.34) Schools is in the “dissimilar” category with 6.35%. These results reveal that the visual complexity values of the buildings at the same education level may differ. Although the school project in İstinye (D=1.30) has ornamental elements on its facade, it has a simpler visual complexity than the facade of Karaağaç School (D=1.35), which is a single-storey design. This is attributed to the higher void ratio on the facade of the Karaağaç School. The lowest average fractal dimension value among the primary schools was found in Mimar Kemal Primary

School (D=1.21). Designed during the Republican era, Mimar Kemal Primary School (1926-1927) features windows devoid of decorative elements, unlike other educational buildings. In addition, the side facade layouts of the building are also quite simple **(Figure 8)**.

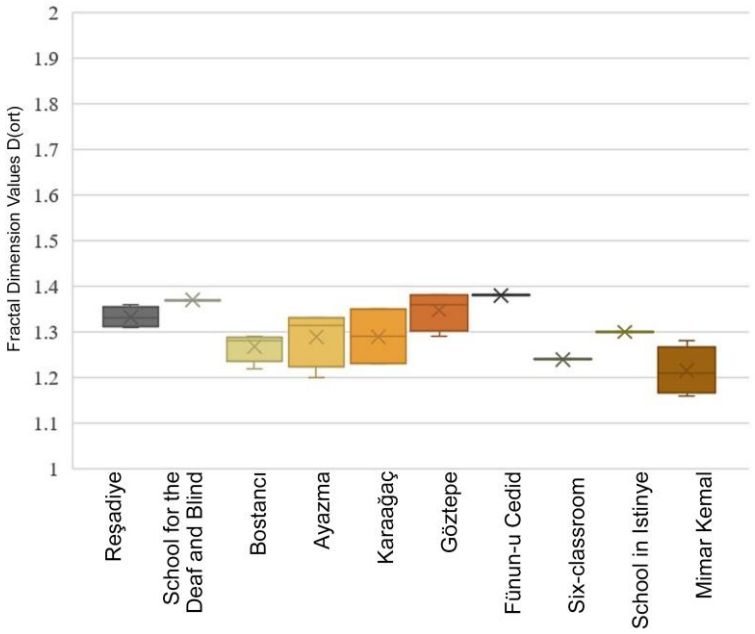


Figure 8: Graph showing fractal dimension values at primary schools (created by author)

When evaluating the madrasa designs, the highest visual complexity value was observed in the Abdülhamid-i Evvel Madrasa project (D=1.43). There are decorative elements such as reverse tassels and plaster on the facade of Abdülhamid-i Evvel Madrasa. The "Madrasa in Medina" has the second-highest visual complexity among the madrasa designs, and its average visual complexity value is "similar" to that of the Abdülhamid-i Evvel Madrasa. Fethiye and Hasanzade Madrasas are "very similar"; Hasanzade and Medrese-tül Kuzat have "similar" visual complexity values. The madrasa building with the lowest average fractal dimension value is Fethiye Madrasa (D=1.24). The simple appearance of the side facades of Fethiye Madrasa supports the findings **(Figure 9a)**.

When the designs of higher education institutions are evaluated, Gedikpaşa Mekteb-i Alisi and Gazi Education Institute designs were found to be "very similar" in terms of average fractal dimensions. The lowest visual complexity level was that of the Dar'ül-Muallimat project (D=1.40). In terms of visual complexity, the Darü'l-Muallimat project is

"dissimilar" to the Gedikpaşa Mekteb-i Alisi and Gazi Education Institute (Figure 9b).

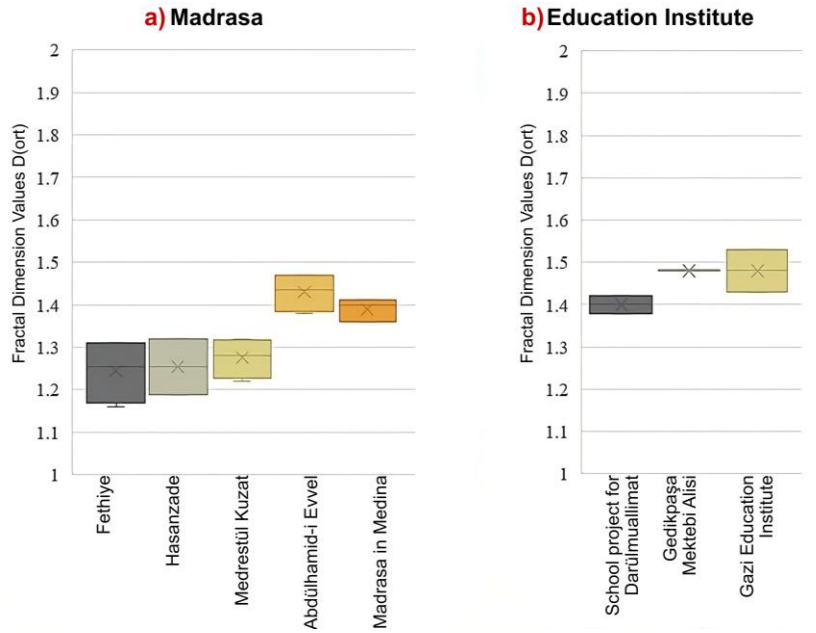


Figure 9: Graphs showing fractal dimensions
a) Madrasas
b) Higher Education Institutions
(created by author)

Considering the findings (Table 4), the fractal dimension values ranged from 1.21 to 1.48. When fractal dimensions are considered according to primary education level, the average fractal dimension values of primary schools are 1.30 and 1.32 for madrasas. The average fractal dimension value for higher education institutions was found to be 1.45. The difference between the average fractal dimension values of primary school and madrasa buildings is considered "similar" at 1.54%. In comparison, the difference between the madrasa and the higher education institution is considered "dissimilar" at 9.85%. In addition, the difference between primary schools and higher education institutions is 11.54%, which is also considered "dissimilar."

Teaching Level	Name	D (ort)	Average Fractal Dimensions Across Education Levels
Primary School	Reşadiye	1.33	1.30
	School for the Deaf and Blind	1.37	
	Bostancı	1.26	
	Ayazma	1.29	
	Karaağaç	1.29	
	Göztepe	1.34	
	Fünun-u Cedid	1.38	
	Six-classroom	1.24	
	School in Istinye	1.30	
	Mimar Kemal	1.21	
Madrasa	Fethiye	1.24	1.32
	Hasanzade	1.25	
	Medresetü'l-Kuzât	1,27	
	Abdülhamid-i Evvel	1,43	
	Madrasa in Medina	1,39	
Higher Education	Dârü'l-Muallimât	1,40	1.45
	Gedikpaşa Mekteb-i Alisi	1,48	
	Gazi Education Institute	1,48	

Table 4: Educational Buildings and Average Fractal Dimensions (created by author)

4.2 Limitations

Within the scope of the research, the restitution projects of the educational buildings built among the eighteen designs were largely reached, but the side facade drawings of the Gazi Education Institute were not available. In addition, all facade drawings of the educational buildings remaining in the design phase have not been accessed. Furthermore, the difficulty in determining the exact design dates for some buildings is a limitation of the research. For this reason, educational buildings were evaluated in two periods: 1909-1919 and after 1925.

5. CONCLUSION

Architect Kemalettin's career, intertwined with government appointments and work primarily on public buildings alongside a technical team of young architects at the Ministry of Foundations, ensured that he played a decisive role in the architectural production of the period (Tanyeli, 2007). This study examines a total of eighteen buildings, ten of which were constructed and eight of which remained in the design phase, by Architect Kemalettin, one of the leading figures

of the First National Architecture Period, between 1909 and 1927, using fractal analysis. These educational buildings are categorized under three headings: primary schools, madrasas, and higher education buildings. The facade drawings were prepared at an outline + primary forms level of detail.

The main findings of the research indicated that the structures remaining in the design phase and the constructed structures have "very similar" characteristics in terms of average visual complexity values. This demonstrates the existence of a consistent fractal order in Architect Kemalettin's design approach, regardless of whether the project was realized or not. Since the visual complexity values of the eighteen buildings do not exhibit chronological continuity, it is not possible to state conclusively that the architect's approach changed over time. However, when examined chronologically, the visual complexity values indicate an increasing trend in higher education institutions and madrasas, while a decreasing trend is observed in primary school buildings. Therefore, there are changes in the architect's design approach. Over time, this can be understood as being related to the categorical differences among educational buildings.

When the buildings were grouped and evaluated by educational level, the average visual complexity values of primary schools and madrasas were found to be "similar." Madrasas were found to be "dissimilar" compared to higher education institutions. Likewise, primary schools and higher education institutions were also found to be "dissimilar." The findings indicate that the facades of primary schools and madrasahs were designed with a similar approach, whereas higher education buildings were constructed with a distinctly different design approach. This finding supports Yavuz's qualitative research (Yavuz, 2009).

In conclusion, these findings indicate that Mimar Kemalettin adopted a design approach that varied according to educational level. This study provides a unique dataset for future research on the educational buildings of the period. Academic studies based on such quantitative data are expected to contribute both to the relevant literature and to a deeper understanding of the architectural identity of the period.

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Conflict of Interest Statement

The manuscript, entitled “Visual Complexity Analysis of Mimar Kemalettin’s Educational Buildings,” has not been published elsewhere and that it has not been submitted simultaneously for publication elsewhere.

AI Use Disclosure

All authors declare that no artificial intelligence tools were used in the writing, analysis, or preparation of this article.

Author Contribution

All authors contributed equally to this article.

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