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Examining Engineering Students' Attitudes Towards Mathematics Using Fuzzy Conjoint Analysis

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Attitude towards mathematics, Engineering students, Fuzzy Conjoint Analysis

Abstract — Attitudes are an important factor influencing individuals' academic success and learning processes. Research indicates that a positive attitude towards mathematics is associated with higher achievement and motivation, while a negative attitude is linked to difficulties. Attitudes towards mathematics shape the academic performance and professional success of students in engineering, as in many other fields. One of the methods used to analyse Likert-type scale data, which is employed to determine ambiguous perceptions and beliefs such as self-efficacy and attitudes, is the Fuzzy Conjoint Analysis. In this study, the attitudes of engineering students towards mathematics were examined using Fuzzy Conjoint Analysis according to various variables. The study was conducted with 382 undergraduate students from different departments of the engineering faculty at a foundation university in Türkiye. The "Attitude Towards Mathematics Scale" was used as the data collection tool. The analysis of the data revealed that the attitudes of engineering students towards mathematics were positive. In addition, it was determined that attitudes towards mathematics showed a low level of difference in favour of females according to the gender variable, in favour of the Industrial Engineering department according to the department variable, and against third-year students according to the grade variable.

Subject classification codes (2020): 97C20; 97M50; 03E72.

1. Introduction

Attitudes, a broad research topic in social psychology and education, are considered an important factor directly influencing individuals' behaviours, learning processes, and academic success. Attitude is a psychological concept that expresses individuals' tendencies and emotional responses towards specific objects, people, events, or subjects. Particularly in the educational context, students' attitudes towards certain courses or disciplines can significantly shape their performance and learning motivation in these areas [4].

Mathematics stands out as a subject perceived as difficult to learn and one where students' attitudes are often negative. Attitude towards mathematics is a composite of students' emotional, cognitive, and behavioural tendencies towards mathematics courses [25]. These attitudes can affect students' interest levels in mathematics courses, their success in these courses, and their career goals related to mathematics [30]. A positive attitude towards mathematics can make students more confident in

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approaching mathematical problems, while a negative attitude can lead to an avoidance of mathematics courses, which can negatively impact academic success in the long term [21].

Mathematics education is also considered a determinant factor for the professional success of engineering students. Mathematics is seen not only as a tool in engineering education but also as a language that facilitates

the understanding and application of engineering concepts [22]. Engineers use mathematical structures and principles in a wide range of activities, from design to analysis, optimization to problem-solving. Due to these facts, deficiencies in basic mathematical skills can cause problems for those receiving engineering education. Additionally, engineering students' attitudes towards mathematics significantly impact their overall academic performance and their preparedness for challenges in their engineering careers.

In the literature, there are many studies examining the relationship between attitudes towards mathematics and various demographic variables (gender, age, socioeconomic status, grade level, etc.) or factors such as academic success, self-efficacy, and problem-solving skills in different samples [3, 5, 10, 12, 23, 26, 29, 31, 32, 35, 40, 43, 46]. Some of these studies have found that attitudes towards mathematics do not show a significant difference in terms of gender [12, 26, 32, 35], while others have found a positive significant relationship between mathematics achievement and attitudes towards mathematics [3, 10, 23, 40, 43, 46]. Additionally, students who develop a positive attitude towards mathematics are also found to have good problem-solving skills and high motivation [29, 31]. Furthermore, Akın [5] found that as the grade level increases, the attitude scores towards mathematics decrease among primary school students in grades 4, 5, 6, 7, and 8. Yıldız [43] also found that high school seniors or high school graduates with a positive attitude towards mathematics tend to choose math-intensive professions.

In studies examining the attitudes of engineering students towards mathematics, it is observed that the sample mostly consists of first-year students and these studies have examined the relationship between attitudes towards mathematics and students' academic success, motivation related to engineering education, general professional expectations, and various demographic variables [6, 16, 28, 29, 36]. Some of these studies and their results are as follows: Nahari [29] did not observe a difference in attitude scores towards mathematics between pre-test and post-test results in his study examining the mathematics skills and attitudes of first-year engineering students. The study also found that students had a high level of positive attitude towards mathematics, low level of mathematics anxiety, and motivation to succeed. Zsoldos-Marchis and Ciascai [50] found a small difference in favour of technical university students in their study comparing the attitudes towards mathematics of preschool and primary education students with technical university students. They found that half of the students liked and thought they knew mathematics. Alibraheim [6] examined the factors affecting the attitudes of first-year engineering students towards mathematics. The study concluded that the reasons shaping students' attitudes towards mathematics could be divided into internal and external factors. Internal factors include reasons originating from the students themselves, such as practice, preparation, assessments, grades, and time management, while external factors include the characteristics of teachers and parental support. Şenay [39] found that the attitudes towards mathematics were positive among students studying in different engineering departments and at different grade levels at a private university in Türkiye. The study also found a low level of difference in favour of females in terms of gender, no significant difference in terms of the department and grade level, and that students enrolled with Undergraduate Placement Exam (UPE) scores had significantly higher attitudes towards mathematics compared to those enrolled with Vertical Transfer Exam (VTE) scores.

1.1. Fuzzy Conjoint Analysis

Fuzzy theory was developed by Zadeh [48]. Zadeh [48] identified that gradeical logic and set theory could not adequately model situations involving uncertainty and fuzziness, leading to the introduction of fuzzy sets and graded membership functions [48]. This approach holds significant importance in fields such as artificial intelligence, control systems, decision support systems, and data analysis [18, 47, 45, 14]. Additionally, studies have shown that the use of fuzzy theory in decision-making processes involving Likert scales is effective in better modelling and analysing situations involving uncertainty and fuzziness [13, 38, 42]. For instance, Ünal and İpekçi [42] transformed artificial data sets into fuzzy form using triangular or trapezoidal fuzzy numbers and evaluated the performance of deep learning techniques with these data using a 5-point Likert scale. They concluded that converting Likert-type data into fuzzy data increased the model's success and that the data were suitable for testing the deep learning model. Traditional Likert scales require definite and clear (agree, strongly disagree, etc.) responses, whereas fuzzy logic evaluates participants' responses with graded membership functions. This allows for more flexible and realistic results in decision-making processes, enabling researchers and decision-makers to develop more effective strategies [38, 42]. The Fuzzy Conjoint Model (FCM) developed by Turksen and Willson [41] allows for more flexible and realistic representations using linguistic variables and fuzzy logic. The input data for FCM are standard fuzzy sets F defined for linguistic evaluations, while the output data are calculated membership fuzzy sets X obtained by linear combinations of the weights of the scale items [34]. For a scale item A_t, the approximate membership degree of y_j in X, $\mu_X\left(y_j^{A_t}\right)$,

$$\mu_X\left(y_j^{A_t}\right) = \sum_{i=1}^{k} W_{\left(r_i^{A_t}\right)} \cdot \mu_{F_i(x_j)} \ , \quad (k = 1, 2, 3, 4, 5) \tag{1}$$

$\boldsymbol{x_j}$ and $\boldsymbol{y_j}$: Numerical values in the F fuzzy sets corresponding to the linguistic variables of the Likert scale $(i, j = 1, 2, 3, 4, 5)$

$\boldsymbol{A_t}$: Scale item, t: item number $(t = 1, 2, 3, \dots T)$, for the Attitude Towards Mathematics Scale, $T = 20$.

$\boldsymbol{\mu_{F_i(x_j)}}$: Membership degrees corresponding to x_j in F_i $(i, j = 1, 2, 3, 4, 5)$

$\boldsymbol{r_i^{A_t}}$: Weights of the responses given by participants to the scale items A_t

$\boldsymbol{W_{\left(r_i^{A_t}\right)}}$: Fuzzified weight for the linguistic rating r_i corresponding to the A_t scale item

$$W_{\left(r_i^{A_t}\right)} = \frac{r_i^{A_t}}{\sum_{i=1}^{j} r_i^{A_t}}$$

$\boldsymbol{\sum_{i=1}^{j} r_i^{A_t}}$: Total weights of the responses given by participants for the A_t scale item

The membership degrees $\mu_{F_i(x_j)}$ for the linguistic variables in the F fuzzy set corresponding to each L were obtained by Zimmermann [49], and the values adapted to the five-point Likert scale are given below.

$F_1 = \left\{\frac{1.00}{1}, \frac{0.75}{2}, \frac{0.50}{3}, \frac{0.00}{4}, \frac{0.00}{5}\right\}$, $F_2 = \left\{\frac{0.50}{1}, \frac{1.00}{2}, \frac{0.75}{3}, \frac{0.25}{4}, \frac{0.00}{5}\right\}$, $F_3 = \left\{\frac{0.00}{1}, \frac{0.50}{2}, \frac{1.00}{3}, \frac{0.50}{4}, \frac{0.00}{5}\right\}$,

$F_4 = \left\{\frac{0.00}{1}, \frac{0.25}{2}, \frac{0.75}{3}, \frac{1.00}{4}, \frac{0.50}{5}\right\}$, $F_5 = \left\{\frac{0.00}{1}, \frac{0.00}{2}, \frac{0.50}{3}, \frac{0.75}{4}, \frac{1.00}{5}\right\}$

In the above representations, for example, the expression $\frac{0.75}{2}$ should be understood not as a ratio but as a membership degree of 0.75 corresponding to the second linguistic variable (agree). The final output of the Fuzzy Conjoint Analysis (FCA) is the similarity degree s. Essentially, s is a fuzzy similarity measure of the sum of Euclidean distances between the corresponding elements of the fuzzy sets F and X [37] and is calculated using the formula provided by Turksen and Wilson [41]as follows:

$$s_j^{A_t}(X,F) = \frac{1}{1+\sqrt{\sum_{i=1}^{k}\left[\mu_X\left(y_j^{A_t}\right)-\mu_{F_j}(y_j^{L_i})\right]^2}} \quad , \quad (k = 1,2,3,4,5) \qquad (2)$$

$\boldsymbol{\mu_{F_j}(y_j^{L_i})}$: Elements of F_j corresponding to the linguistic terms L_i.

Fuzzy set theory has been applied in many fields such as social sciences, business, finance, management, economics, marketing, engineering, and health sciences [2, 7, 9, 20, 33, 44]. Various studies in the field of education have shown that fuzzy sets can be used to represent linguistic variables in Likert-type scales [17, 19, 24, 34].

The fuzzy sets method is considered a valid and more dependable alternative to traditional techniques, such as using means or percentages, for the analysis of questionnaire data [2]. While using the mean or percentage can be persuasive, the fuzzy sets approach provides a more precise assessment of the variability within and across the ratings on the Likert scale [1]. Gopal et al. [17] stated that the use of FCA offered insights into students' perceptions, highlighting their levels of mathematics self-efficacy and anxiety. Moreover, they identified the attributes that most significantly influenced students' rating patterns. Recognizing attributes perceived negatively or neutrally provides valuable information for educational stakeholders, helping them understand the challenges and uncertainties students encounter, thereby enhancing the mathematics teaching and learning process.

Research indicates that students' positive attitudes towards mathematics generally lead to higher academic success and professional motivation, while negative attitudes cause difficulties in mathematics and related courses. Therefore, examining attitudes towards mathematics of engineering students is important in providing insights into how mathematics is taught and how it should be taught. Additionally, it is important to investigate the variables that influence engineering students' attitudes towards mathematics. In this context, it is considered beneficial to determine the levels of attitude towards mathematics based on variables such as gender, department, and grade level.

This study aims to determine the level of engineering students' attitudes towards mathematics according to various variables using the FCA method. In this context, it is thought that the findings and results of the study will shed light on the measures to be taken and the planning to be made in the training of engineers. Additionally, the absence of a study examining the attitudes of engineering students towards mathematics according to various variables using FCA in Türkiye makes this study significant in terms of its contribution to the literature.

According to the purpose of the study, the following problems will be addressed:

1) What is the level of engineering students' attitudes towards mathematics?

2) What is the level of engineering students' attitudes towards mathematics according to the gender variable?

3) What is the level of engineering students' attitudes towards mathematics according to the department variable?

4) What is the level of engineering students' attitudes towards mathematics according to the grade variable?

2. Method

In this study, a descriptive survey model was employed to examine engineering students' attitudes towards mathematics based on the variables of gender, department, and grade level. Such a design aims to explore existing relationships, prevailing beliefs, observable effects, or emerging trends. It is classified as non-experimental since it examines associations among variables without manipulating them [8].

2.1. Study Group

Although there are differences on syllabuses among universities across Türkiye, generally all engineering students take basic mathematics courses such as Calculus-1 and Calculus-2 in the first year, and Linear Algebra and Differential Equations in the second year. In addition to these courses, each department offers additional mathematics courses according to their needs, such as "Discrete Computational Structures," "Numerical Analysis," "Applied Engineering Mathematics," or "Probability and Statistics." The basic mathematics courses, defined as service courses, are usually taught by faculty members who are mathematics specialists, while the additional mathematics courses are taught by engineering-based faculty members. This situation is also valid for the university where the study was conducted.

The study included 382 undergraduate students randomly selected from different departments of the engineering faculty at a foundation university in Türkiye. The distribution of participants according to the independent variables of gender, department, and grade is given in Table 1.

Table 1. Distribution of participants according to independent variables

Variable	Category	N	%
Gender	Female	107	28
	Male	275	72
Department	Computer	55	14,4
	Mechanical	45	11,8
	Mechatronic	66	17,3
	Materials and Nanotechnology	13	3,4
	Civil	88	23
	Industrial	46	12
	Electrical-Electronics	69	18,1
Grade	1st Year	122	31,9
	2nd Year	136	35,6
	3rd Year	47	12,3
	4th Year	77	20,2

2.2. Data Collection Tools

Descriptive methods use scales or surveys to gather information from participants. In this study, the "Attitude Towards Mathematics Scale" was used as the data collection tool. Scales are useful when the researcher is interested in perceptions, beliefs, attitudes, or opinions. Additionally, a "Personal Information Form (PIF)" was used to collect information on the participants' gender, department and grade.

2.2.1. Attitude Towards Mathematics Scale

In our study, the Attitude Towards Mathematics Scale (ATMS) developed by Çelik and Bindak [12] was used to determine the attitudes of engineering students towards mathematics. This scale has been used in previous studies. The scale consists of 20 items in a 5-point Likert format, with 10 items being negative. The Likert scale levels, and their representations are given in Table 2. According to FCA, the participation level ranges are as follows: 0.0-0.2 → Strongly Disagree, 0.2-0.4 → Disagree, 0.4-0.6 → Neutral, 0.6-0.8 → Agree, 0.8-1.0 → Strongly Agree. Before the analyses, reverse coding was applied for negative items. Çelik and Bindak [12] calculated the Cronbach's alpha reliability coefficient of the scale as $\alpha = 0.882$. In this study, the reliability analysis of the scale was repeated, and the Cronbach's alpha reliability coefficient was calculated as $\alpha = 0.883$. According to George and Mallery [15], this value is considered "good."

Table 2. Likert Scale Levels and Their Representations

Likert Scale Levels	Linguistic Variable	Representation
1	Strongly Disagree	L1
2	Disagree	L2
3	Neutral	L3
4	Agree	L4
5	Strongly Agree	L5

2.3. Data Collection

The research data were collected in written form during face-to-face sessions in the fall semester of the 2019-2020 academic year. Participants completed the PIF and ATMS in a single session. The application duration was approximately 15 minutes.

2.4. Data Analysis

This section explains the process of evaluating the data using the FCA approach employed in the study. The s value ($s_i^{A_t} \in [0,1]$) corresponding to each linguistic variable reflects the strength of the degree of participation for each scale item [2]. As $s_i^{A_t}$ approaches 1, the strength of the degree of participation increases. After finding the $s_i^{A_t}$ values, the highest $s_i^{A_t}$ value $s^*(A_t)$ and the associated linguistic rating $L(s^*(A_t))$ are determined, representing the overall rating. $s^*(A_t)$ and $L(s^*(A_t))$ represent the highest degree of participation for the relevant scale item. Thus, the preferred type of perception (positive, negative, or neutral) for that scale item is determined. For example, for item 15 of the ATMS, "Mathematics does not scare me," if $L(s^*(A_{15}))$ equals L_4 or L_5, it indicates a positive perception towards mathematics; if it equals L_1 or L_2, it indicates a negative perception; if it equals L_3, it indicates neutrality.

Subsequently, the number of $L(s^*(A_t))$ values corresponding to the $s^*(A_t)$ value for each scale item is determined for the entire scale. The highest number of $L(s^*(A_t))$ values reveal the students' attitudes towards mathematics. The found $s^*(A_t)$ values are then ranked from highest to lowest. The scale item with the lowest rank number is interpreted as the item that most significantly (positively) affects the attitude towards mathematics [34, 37, 17]. For example, if $L(s^*(A_t)) = L_4$ in 8 items and $L(s^*(A_t)) = L_5$ in 7 items of the 20-item ATMS, this indicates that the participant group's attitudes towards mathematics are highly positive. The FCA calculation process for item 1 of the ATMS applied to engineering students is shown below.

1) Distribution of responses to ATMS-1 (shortly A1): $n_1 = 7,\ n_2 = 24,\ n_3 = 43,\ n_4 = 154,\ n_5 = 154$

2) Weights of responses to A1: $r_1^{A_1} = 7.1 = 7,\quad r_2^{A_1} = 24.2 = 48,\quad r_3^{A_1} = 43.3 = 129,\quad r_4^{A_1} = 154.4 = 616,\quad r_5^{A_1} = 154.5 = 770$

3) Total weights of responses to A1: $\sum_{i=1}^{5} r_i^{A_1} = 7 + 48 + 129 + 616 + 770 = 1570$

4) Fuzzified weights for each rating $W_{\left(r_i^{A_1}\right)}$: $W_{\left(r_1^{A_1}\right)} = \frac{7}{1570} = 0{,}004459,\quad W_{\left(r_2^{A_1}\right)} = \frac{48}{1570} = 0{,}030573,\quad W_{\left(r_3^{A_1}\right)} = \frac{129}{1570} = 0{,}082166,\quad W_{\left(r_4^{A_1}\right)} = \frac{616}{1570} = 0{,}392357,\quad W_{\left(r_5^{A_1}\right)} = \frac{770}{1570} = 0{,}490446$

5) Membership degrees $\mu_X\left(y_j^{A_t}\right)$:

$$\mu_X(y_1^{A_1}) = W_{\left(r_1^{A_1}\right)}\ \mu_{F_1(x_1)} + W_{\left(r_2^{A_1}\right)}\ \mu_{F_2(x_1)} + \cdots + W_{\left(r_5^{A_1}\right)}\ \mu_{F_5(x_1)}$$

$$= 0{,}004459.(1) + 0{,}030573.(0{,}5) + 0{,}082166.(0) + 0{,}392357.(0) + 0{,}490446.(0)$$

$$= 0{,}019745$$

$$\mu_X(y_2^{A_1}) = 0.173089,\quad \mu_X(y_3^{A_1}) = 0{,}646815,\quad \mu_X(y_4^{A_1}) = 0{,}808917,\quad \mu_X(y_5^{A_1}) = 0{,}686624$$

6) Similarity degree $s_j^{A_1}(X, F)$ (shortly $s_j^{A_1}$) :

$$s_1^{A_1} = \frac{1}{1 + \sqrt{\left[\mu_X(y_1^{A_1}) - \mu_{F_1}(y_1^{L_1})\right]^2 + \left[\mu_X(y_2^{A_1}) - \mu_{F_1}(y_1^{L_2})\right]^2 + \cdots + \left[\mu_X(y_5^{A_1}) - \mu_{F_1}(y_1^{L_5})\right]^2}}$$

$$= \frac{1}{1+\sqrt{[0{,}019745-1]^2+[0{,}173089-0{,}75]^2+[0{,}646815-0{,}5]^2+[0{,}808917-0]^2+[0{,}686624-0]^2}}$$

$$= 0{,}39026$$

Similarly, $s_2^{A_1} = 0{,}433416,\quad s_3^{A_1} = 0{,}528038,\quad s_4^{A_1} = 0{,}770926,\quad s_5^{A_1} = 0{,}718446$. In this case, $s^*(A_1) = s_4^{A_1} = 0{,}770926$ and $L(s^*(A_1)) = L_4$.

Calculations for FCA were made after the responses to the ATMS were entered into the MS Excel program.

3. Findings

In this section, the findings related to our research problems are presented. Accordingly, detailed FCA results are given only for first problem and not for the other problems.

3.1. Findings Related to the First Problem

To answer the research problem "What is the level of engineering students' attitudes towards mathematics?", the results obtained with the FCA for the items of the ATMS are presented in Table 3.

Table 3. FCA results according to the items of ATMS

Scale Item	L_1	L_2	L_3	L_4	L_5	$s^*(A_t)$	$L(s^*(A_t))$	Rank
A_1	0,390260	0,433416	0,528038	0,770926	0,718446	**0,770926**	L_4	14
A_2	0,390179	0,434205	0,531053	0,780929	0,710680	**0,780929**	L_4	12
A_3	0,420847	0,487358	0,622476	0,787105	0,593719	**0,787105**	L_4	9
A_4	0,383783	0,422954	0,511270	0,742843	0,753131	**0,753131**	L_5	16
A_5	0,394651	0,440706	0,541695	0,782798	0,697481	**0,782798**	L_4	11
A_6	0,392085	0,438603	0,540022	0,807379	0,689163	**0,807379**	L_4	4
A_7	0,405890	0,460267	0,576183	0,807163	0,646485	**0,807163**	L_4	5
A_8	0,418283	0,486311	0,634364	0,785158	0,585446	**0,785158**	L_4	10
A_9	0,398046	0,447739	0,556077	0,806175	0,672084	**0,806175**	L_4	6
A_{10}	0,407259	0,465773	0,593005	0,820408	0,623926	**0,820408**	L_4	1
A_{11}	0,432602	0,507881	0,657960	0,744269	0,565444	**0,744269**	L_4	18
A_{12}	0,406075	0,460096	0,573372	0,807687	0,648661	**0,807687**	L_4	3
A_{13}	0,412172	0,469435	0,589173	0,796694	0,631957	**0,796694**	L_4	7
A_{14}	0,396905	0,443047	0,542530	0,778590	0,696840	**0,778590**	L_4	13
A_{15}	0,408781	0,464783	0,581949	0,808989	0,637651	**0,808989**	L_4	2
A_{16}	0,434968	0,507944	0,652500	0,733963	0,572958	**0,733963**	L_4	19
A_{17}	0,517350	0,623214	0,674052	0,581799	0,492209	**0,674052**	L_3	20
A_{18}	0,388910	0,428969	0,518196	0,738427	0,746355	**0,746355**	L_5	17
A_{19}	0,427884	0,494757	0,626741	0,761501	0,592520	**0,761501**	L_4	15
A_{20}	0,399626	0,448028	0,552725	0,787978	0,681201	**0,787978**	L_4	8

From Table 3, it is understood that the rank numbers for the linguistic variables of ATMS are as follows: L1=0, L2=0, L3=1, L4=17 and L5=2. According to these data, the fact that 17 out of the 20 items of ATMS responded are at the L4 level (0.6-0.8 → Agree) and 2 items responded are at the L5 level (0.8-1.0 → Strongly Agree) indicates that engineering students have a positive attitude towards mathematics. The scale item that has the most significant impact on demonstrating attitudes towards mathematics is A10 (s=0.820408, L4: Agree) with a rank number of "1", while the item with the least impact is A17 (s=0.674052, L3: Neutral) with a rank number of "20".

3.2. Findings Related to the Second Problem

To answer the research problem "What is the level of engineering students' attitudes towards mathematics according to the gender variable?", the ATMS rank numbers obtained with the FCA are presented in Table 4.

Table 4. ATMS Rank numbers Obtained with FCA According to the Gender Variable

Gender	L_1	L_2	L_3	L_4	L_5
Female	0	0	1	16	3
Male	0	0	1	17	2

From Table 4, it is understood that the rank numbers for the linguistic variables of ATMS are as follows: for women; L1=0, L2=0, L3=1, L4=16 and L5=3, and for men; L1=0, L2=0, L3=1, L4=17 and L5=2. According to these data, the fact that 16 out of the 20 items of ATMS for women are at the L4 level (0.6-0.8 → Agree) and 3 items are at the L5 level (0.8-1.0 → Strongly Agree), and for men, 17 items are at the L4 level (0.6-0.8 → Agree) and 2 items are at the L5 level (0.8-1.0 → Strongly Agree), indicates that students' attitudes towards mathematics are positive for both genders. However, the fact that the rank number of L5 level preferences is one higher for women than for men suggests that, although the difference is slight, the positive attitude towards mathematics is somewhat more pronounced among women.

3.3. Findings Related to the Third Problem

To answer the research problem "What is the level of engineering students' attitudes towards mathematics according to the department variable?", the ATMS rank numbers obtained with the FCA are presented in Table 5.

Table 5. ATMS Rank numbers Obtained with FCA According to the Department Variable

Department	L_1	L_2	L_3	L_4	L_5
Computer engineering	0	0	1	18	1
Mechanical engineering	0	0	1	18	1
Mechatronic engineering	0	0	1	18	1
Materials and Nanotechnology engineering	0	0	1	17	2
Civil engineering	0	0	1	17	2
Industrial engineering	0	0	1	15	4
Electrical-Electronics engineering	0	0	1	18	1

When Table 5 is examined, it is seen that the rank numbers for the linguistic variables of ATMS are the same at the L3 level for all departments (L3=1), and the total rank number of levels indicating a positive attitude, L4 and L5, are equal (L4 + L5 = 19). Accordingly, it can be said that the attitudes of students from all departments towards mathematics are positive. However, considering the rank numbers at the L5 level (0.8-1.0 → Strongly Agree), which indicates the highest level of positive attitude, there is a difference in favor of the Industrial Engineering Department students.

3.4. Findings Related to the Fourth Problem

To answer the research problem "What is the level of engineering students' attitudes towards mathematics according to the grade variable?", the ATMS rank numbers obtained with the FCA are presented in Table 6.

Table 6. ATMS Rank numbers Obtained with FCA According to the Grade Variable

Grade	L_1	L_2	L_3	L_4	L_5
1st	0	0	1	18	1
2st	0	1	0	17	2
3st	0	0	3	15	2
4st	0	0	1	18	1

When Table 6 is examined, it is seen that the L3 rank numbers for the linguistic variables of ATMS are the same for the 1st and 4th grades (L3=1), but different for the 2nd and 3rd grades (L2=1, L3=3, respectively). Additionally, the total rank numbers of levels indicating the positive attitude, L4 and L5, are the same for the 1st, 2nd, and 4th grades ($L4 + L5 = 19$), but different for the 3rd grade ($L4 + L5 = 17$). Accordingly, it can be said that attitudes towards mathematics are positive for all grades, but this is less pronounced for 3rd grade students compared to other grades.

4. Discussion

This study aimed to examine the attitudes of engineering students towards mathematics according to various variables using FCA. Accordingly, for the first research problem, it was concluded that engineering students have a positive attitude towards mathematics. This result is consistent with the findings of Nahari [29], Zsoldos-Marchis and Ciascai [50], and Alibraheim [6]. This may be a result of students who choose engineering, a discipline where mathematics is frequently used, having positive attitudes towards mathematics from their previous school periods. Indeed, Morán-Soto and Benson [28] stated that engineering students have high self-efficacy beliefs in mathematics from high school and believe they can perform well in university mathematics courses despite some deficiencies in their mathematical competencies. Similarly, Yıldız [43] noted that high school seniors or graduates with positive attitudes towards mathematics tend to choose math-oriented professions.

For the second research problem, it was found that although both male and female engineering students have positive attitudes towards mathematics, there is a slight difference in favour of females. According to FCA, this difference stems from the responses to A1 and A5 items, which are related to "love mathematics and the study of mathematics". This may be a result of female engineering students love mathematics from their previous school periods. Indeed, Giannoulas and Stampoltzis [16] also noted that females scored higher in mathematics attitude due to previous experience factors.

As a result of the FCA conducted for the third research problem of the study, it was seen that the attitudes of engineering students towards mathematics were positive and there was a difference only in favour of the Industrial Engineering Department students according to the department variable. According to FCA, this difference stems from the responses to A1 and A2 items, which are related to "love mathematics classes and using mathematics in their lives". This may be because students realize the importance of using mathematics in non-mathematics courses and that they will need mathematics in their work environments. Conversely, Cardella [11] noted that some practicing engineers believe that the mathematics they learned in university is not applicable to their daily work.

For the fourth research problem, it was found that attitudes towards mathematics are positive according to the grade variable, but this is less pronounced for 3rd grade students compared to other grades. According to FCA, this difference stems from the responses to A11 and A16 items, which are related to the "desire to engage with mathematics outside of class and mathematics exam anxiety". This may be because students who enrolled in the 3rd grade through the VTE have lower mathematics achievement compared to others, resulting in less positive attitudes towards mathematics. This result is also consistent with McLeod's [27] idea that beliefs about mathematics are more deep-rooted and stable, and therefore more resistant to change, compared to daily attitudes towards mathematics classes, which are sensitive to classroom factors and frequently change. On the other hand, the insufficient establishment of the relationship between engineering and mathematics in the given courses may also have contributed to this situation.

Finally, the results obtained with FCA in this study were found to be consistent with the results obtained by Şenay [39] using statistical analysis techniques with the same data. This shows that, as in previous studies, FCA is a reliable method for evaluating Likert scale data.

5. Conclusion and Recommendations

As a result of the research, we can say that engineering students' attitudes towards mathematics are positive, and this situation does not change according to gender, department and class variables. In fact, it is desirable and expected that engineering students have positive attitudes towards mathematics. On the other hand, it was also seen that FCA is a reliable method that can be used in educational research. To further develop positive attitudes towards mathematics of engineering students, to train more qualified engineers, and through the usage of FCA the following recommendations can be made:

- Conducting studies comparing the mathematics self-efficacy, mathematics anxiety, and beliefs and attitudes towards mathematics courses of engineering students in different departments and grade levels will contribute to shaping engineering education.
- Study results previously obtained with statistical methods can be compared with the same data using FCA. Thus, more reliable results can be obtained.
- Conducting similar studies with engineering faculty students from different universities in Türkiye will fill the gap in the literature.

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