Analysis of Chemistry Test Topics in the Higher Education Institutions Examination Using the DEMATEL Method

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The aim of this study is to analyze the distribution of chemistry questions and the relationships between topics in the Higher Education Institutions Examination (YKS) Basic Proficiency Test (TYT) and Field Proficiency Test (AYT) from 2018 to 2024, based on the Secondary School Chemistry Curriculum, using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. The research was conducted using the document analysis technique, a qualitative research method, leveraging data obtained from the database of the Measurement, Selection, and Placement Center (MSPC). Initially, the chemistry questions included in the TYT and AYT sections of the YKS between 2018 and 2024 were classified according to the topics in the Secondary School Chemistry Curriculum. The relationships between these topics were then evaluated using the DEMATEL method. Findings reveal that in the TYT chemistry section, topics such as "Atoms and the Periodic Table", "Interactions Between Chemical Species", and "Mixtures" appeared consistently in the exams each year, while no questions were related to the "Nature and Chemistry" unit. Regarding the topic distribution of AYT chemistry questions, it was determined that the most frequently addressed topics were "Chemistry and Electricity," "Liquid Solutions and Solubility", "Chemical Equilibrium", "Organic Compounds", and "Gases". Conversely, no questions were asked on "Energy Resources and Scientific Developments". When analyzing the relationships among TYT topics using DEMATEL, it was found that the topic "Chemistry Everywhere" interacted the most with other topics, while "Structure of the Atom and the Periodic Table" had the greatest influence on other topics. Similarly, when examining the relationships among AYT topics, "Chemistry and Electricity" was identified as the most interactive and influential topic. The findings of this study provide important insights for students on which topics to prioritize during their exam preparation. Additionally, this study suggests that analyses conducted using the DEMATEL method can serve as a model for evaluating curricula in other disciplines.

Keywords: Higher education institutions examination, chemistry questions, secondary school chemistry curriculum, Dematel.

INTRODUCTION

In Türkiye, with increasing participation among final-year high school students and graduates, nearly all candidates take the Higher Education Institutions Examination (YKS) annually. This single-stage exam, administered by the Measurement, Selection, and Placement Center (ÖSYM), integrates both selection and placement processes for student admission to higher education programs. While the system selects a group of students based on preferences and performance rankings, other candidates are placed in universities within the available quotas, and a significant portion is eliminated. The YKS consists of three sessions: the Basic Proficiency Test (TYT), the Field Proficiency Test (AYT), and the Foreign Language Test (YDT). The Basic Proficiency Test, administered in the first session, is mandatory for all candidates, while the Field Proficiency Test and the Foreign Language Test, conducted in the second and third sessions, respectively, are optional. Although the YKS covers all scientific disciplines, this study focuses solely on chemistry questions in the TYT and AYT tests. The TYT, the first session of the YKS, includes questions from the following sections: Turkish (40 questions), Social Sciences (20 questions), Basic Mathematics (40 questions), and Science (20 questions). The Science section consists of questions from physics (7), chemistry (7), and biology (6), with 35% of the questions covering physics, 35% chemistry, and 30% biology topics. The optional AYT's Science Test includes a total of 40 questions: physics (14), chemistry (13), and biology (13) (Measurement, Selection, and Placement Center [ÖSYM], 2024a). These data highlight the significant weight of chemistry questions in the overall distribution of YKS questions.

An analysis of the average scores from the Science section of the TYT, consisting of 20 questions, in YKS examinations administered between 2018 and 2024 (Measurement, Selection, and Placement Center [ÖSYM], 2024b), reveals that the average raw scores are lower than the standard deviation values. This indicates a broad range in exam results, reflecting significant differences in participants' performance levels. Such findings suggest that the TYT is both challenging and discriminative (Table 1). Similarly, the average scores from the chemistry subsection of the Science Test in the AYT demonstrate that the raw scores are also lower than the standard deviation values. This further indicates that the chemistry

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subsection differentiates candidates' performance levels, suggesting a test structure that is both rigorous and distinguishing (Table 2).

Table 1. Means and Standard Deviations of the Science Questions in the YKS Basic Proficiency Test

Science Questions in the TYT (Basic Proficiency Test)						
	Candidates Enrolled in the Final Year of Secondary Education Institutions			All Candidates		
Year	**Number of Candidates ***	**Mean**	**Standard Deviation**	**Number of Candidates ***	**Mean**	**Standard Deviation**
2018	935.698	3,296	4,438	2.260.273	2,828	4,095
2019	970.240	2,704	4,152	2.390.188	2,243	3,77
2020	881.059	3,247	4,513	2.295.890	2,668	4,086
2021	935.058	3,796	4,363	2.416.748	3,212	4,097
2022	901.757	3,937	4,631	3.008.029	3,231	4,043
2023	855.467	3,546	4,894	2.995.399	2,909	4,213
2024	1.093.334	3,478	4,549	2.819.075	2,861	3,989

* Candidates with Valid Results in the Relevant Test

Table 2. Means and Standard Deviations of Chemistry Questions in the YKS Field Proficiency Science Test

Chemistry Questions in the AYT (Field Qualification Tests)						
	Candidates Enrolled in the Final Year of Secondary Education Institutions			All Candidates		
Year	**Number of Candidates ***	**Mean**	**Standard Deviation**	**Number of Candidates ***	**Mean**	**Standard Deviation**
2018	850.195	1,336	2,827	1.877.568	1,109	2,542
2019	847.407	1,186	2,695	1.880.711	0,963	2,429
2020	719.711	1,746	3,486	1.672.309	1,416	3,188
2021	741.214	1,991	3,268	1.627.083	1,891	3,195
2022	707.612	1,734	3,096	1.852.635	1,593	2,899
2023	692.459	1,768	3,169	1.980.480	1,483	2,773
2024	863.976	1,457	2,718	1.776.449	1,308	2,483

* Candidates with Valid Results in the Relevant Test

A review of the literature reveals that various studies have examined the questions in Turkey's higher education entrance exams, including the Higher Education Institutions Examination (YKS), University Entrance Exam (YGS), Undergraduate Placement Exam (LYS), and Student Selection Exam (ÖSS), focusing on mathematics, physics, chemistry, and biology test questions (Aladağ, & Duran, 2016; Atav, & Morgil, 1999; Çoban, & Hançer, 2006; Çoban, Aktaş, & Sülün, 2006; Çoban, Uludağ & Yılmaz, 2006; Dursun & Aydın Parim, 2014; Efe, & Temelli, 2003; Gacanoğlu, & Nakiboğlu, 2022; Gacanoğlu, 2024a; Gacanoğlu, 2024b; Kadayıfçı, 2007; Karaman, Salar, Dilber, & Turgut, 2019; Keleş, & Karadeniz, 2015; Kızılçaoğlu, 2004; Morgil, & Bayarı, 1996; Morgil, Yılmaz, Seçken, Yılmaz, & Yücel, 1995; Özden, 2007; Özmen, 2005; Sönmez, 2020; Yamak, Ayvacı, & Duru, 2018).

Despite numerous studies, no research has specifically examined the results of the chemistry test in the YKS since its implementation in 2018, based on ÖSYM data. The evaluation reports by ÖSYM (2018, 2019, 2020, 2021) have assessed the chemistry test results in terms of mean scores and standard deviations. However, these reports have not provided an explicit evaluation of the topic distribution or the relationships among topics. Furthermore, no studies have been found in the literature that analyze the relationships among the topics covered in chemistry questions in the YKS exams between 2018 and 2024 or prioritize topics based on their importance.

Research focusing on the characteristics of chemistry questions in higher education entrance exams began with the study by Morgil et al. (1995), which analyzed the distribution of chemistry questions from 1974 to 1994 by topic, difficulty level, and alignment with the high school Secondary School Chemistry Curriculum. Özmen (2005) classified 223 chemistry questions from the ÖSS exams (1990–2005) according to topics and Bloom's taxonomy, concluding that 72% of the questions corresponded to the first three levels of Bloom's taxonomy, while 28% fell into the last three levels.

Özden (2007) examined the chemistry questions in the ÖSS 2006 exam in terms of scope and difficulty, finding that they aligned well with the high school curriculum but noted an unequal distribution across topics. Çoban at al. (2006) analyzed ÖSS chemistry questions from 2001–2005, revealing that while topics from 10th-grade chemistry were emphasized, 12th-grade topics were often neglected, indicating issues with content validity.

More recent studies, such as those by Gacanoğlu and Nakiboğlu (2022), analyzed the TYT and AYT chemistry questions in YKS between 2019-2021, according to the objectives of the 2018 secondary chemistry curriculum, and assessed the subject content validity of the exams. According to the results of their study, they found that the TYT chemistry questions were mainly based on the 9th and 10th grade objectives, while the AYT chemistry questions were mainly based on the 11th and 12th grade objectives. In addition, it was found that the acquisition of the "Nature and Chemistry" and "Energy Resources and Scientific Developments" units were not included at all in the YKS exams administered between 2019 and 2021.

Gacanoğlu (2024) analysed the biology test questions in the YKS exams between 2019 and 2023 within the framework of the objectives of the 2018 Secondary School Biology Course Curriculum and compared them with the results of Gacanoğlu and Nakiboğlu's (2022; 2024) study on the YKS chemistry test questions. The analysis revealed that the majority of questions in the YKS exams were derived from the 11th grade 'Human Physiology' unit of the 2018 curriculum for the biology course. The study further concluded that there was an absence of homogeneity in terms of the acquisitions in the YKS exam biology tests. This finding was consistent with the results reported by Gacanoğlu and Nakiboğlu (2022), who found that the 2019-2023 YKS chemistry questions did not fully achieve content validity in terms of the curriculum gains. The study also noted the absence of questions related to the 'Energy Resources and Scientific Developments' unit.

Gacanoğlu and Nakiboğlu (2024) evaluated the chemistry questions in YKS-2023 TYT and AYT exams in terms of content validity within the framework of the 2018 Secondary Education Chemistry Course Curriculum objectives, and compared the results with those of YKS-2020 TYT and AYT chemistry questions. The study's findings concluded that the limitations imposed on the acquisitions for the YKS exams during the pandemic and earthquake process did not have an effect on the chemistry acquisitions. However, the questions in the exam differed according to the acquisitions and unit-based distribution. As demonstrated in the extant literature, chemistry questions have been examined in terms of subject, curriculum and Bloom's classification. However, there is an absence of studies that address the relationship between the subjects of chemistry questions in the tests within the scope of 2018-2024 YKS exams and the evaluations related to which subjects are prioritized in the exams. Conducting evaluations in this direction is of paramount importance, as it will empower candidate students to prepare for the exam accordingly.

The present study was conducted with the objective of classifying the chemistry questions in the TYT and AYT tests applied in YKS exams according to the subjects of the 2018 chemistry curriculum, and to prioritise the weights of the exam subjects on the basis of the relationship between the subjects. To the best of the author's knowledge, no study has hitherto been conducted in Turkey on the analysis of chemistry questions asked in the YKS exam conducted by ÖSYM with multi-criteria decision-making methods. However, a few researchers in the field of education have conducted studies with DEMATEL, a multi-criteria decision-making method (Ahmadi, Nourmohamadzadeh, & Amiri,2023; Aksoy,& Kocakoç, 2024; Özdemir & Topal, 2019; Ranjan, Chatterjee, & Chakraborty, 2015).

In view of the aforementioned data, the primary objective of this study is to ascertain the significant interactions between the subject areas constituting the chemistry questions posed in the Higher Education Institutions Examination (YKS) during the period 2018-2024. The secondary objective is to provide candidates preparing for the university examination with a more precise understanding of the critical subject areas, thereby enhancing their performance in the chemistry test. The general objective outlined above is to be analysed within the framework of two sub-objectives: The first sub-objective is to classify the chemistry questions asked in the Basic Proficiency Test (TYT) and Field Proficiency Test (AYT) within the scope of YKS according to the topics in the 2018 chemistry curriculum. The second sub-objective is to analyse the existing relationships between the chemistry questions asked in TYT and AYT on the basis of subjects.

In this context, an attempt was made to ascertain the causal relationships between the subjects of chemistry questions in TYT and AYT in the YKS examination. The objective of this study was to determine which subject is prioritised and considered to be more significant than the others, and which subject is the subject that is affected or influenced by the DEMATEL method.

METHOD

This study utilized secondary data obtained through document analysis, a qualitative study design, and DEMATEL, a multi-criteria decision-making method. The study focused on chemistry questions from the Higher Education Institutions Examination conducted by ÖSYM between 2018 and 2024. The data for the study came from the Higher Education Institutions Examination TYT and AYT tests conducted by ÖSYM between 2018 and 2024 (ÖSYM, 2024b).The study classified a total of 147 chemistry questions asked in the Higher Education Institutions Examination between 2018 and 2024 according to the subjects in the 2018 chemistry curriculum. The DEMATEL method was used to determine the relationship between the subjects that form the basis of chemistry questions and the importance levels of the subjects. The DEMATEL method determined the importance of ranking of the subjects of the exam questions, the influencing and influenced criteria. This study used real data to determine the direct and indirect relationships between the subjects of chemistry questions asked in the Higher Education Institutions Examination by using the DEMATEL method.

The DEMATEL Method

The DEMATEL Method, as introduced by Fonetla and Gabus in 1971 (Gabus & Fontela, 1973; 1976), employs a structured modelling approach to address complex problems involving multiple interrelated criteria. The DEMATEL Method systematically constructs and analyses a structural model using directed graphs or diagrams. This model categorizes multiple criteria into cause-and-effect groups, thereby enabling the identification of causal relationships between criteria. The resulting influence map facilitates the analysis of problems related to nested clusters and allows for the determination of the levels of interaction between criteria by visualizing the directed relationship between them (Tzeng & Huang, 2011).

The present study employs the DEMATEL technique to quantitatively ascertain the interrelationships between the examination subjects, with the objective of enhancing the performance of candidates in the chemistry section of the YKS examination. In this context, both direct and indirect effects between multiple subjects have been considered (Dey, Kumar, Ray & Pradhan, 2012; Tzeng & Huang, 2011). The DEMATEL method has been employed over the years to address a variety of complex and practical decision-making problems, such as aviation safety assessments (Liou, Tzeng, & Chang, 2007), supplier selection (Dey, Kumar, Ray & Pradhan, 2012), the selection of optimal new urban infrastructure for fire and emergency services in Istanbul (Nyimbili, Erden & Mwanaumo, 2023), and the assistance provided to countries in quarantine decisions due to the COVD-19 pandemic (Altuntas & Gok, 2021). The fundamental steps of the DEMATEL method are outlined below (Hsu, W, Kuo, Chen & Hu, 2013; Wu, 2008).

Step1: Constructing the Direct Relationship Matrix

The direct relationship matrix (A) is created by scoring the relationships between criteria using a scale ranging from 0 to 4 (Table 3).

Table 3. DEMATEL Method Comparison Scale

Numerical Value	Definition
0	No influence
1	Low influence
2	Moderate influence
3	High influence
4	Very high influence

In the scale, '0' indicates no influence, '1' represents low influence, '2' denotes moderate influence, '3' signifies high influence, and '4' indicates very high influence. The relationships among criteria are determined by an expert group using the influence scale provided in Table 3. Experts are selected based on their experience in line with the objectives of the study. According to Khorramshahgol and Moustakis (1988), the number of experts whose opinions are sought should be limited to five to 15. The consistency ratio (Saaty ,1987) is a metric used to ascertain the consistency of the pairwise comparisons made by the expert group, decision criteria and alternatives. A consistency ratio of zero or close to zero indicates that the decisions of the expert group in pairwise comparisons are consistent, and an inconsistency value up to 0.10 is generally considered acceptable. Should the ratio exceed 0.10, it is recommended that the expert group reconsider its decisions in pairwise comparisons (Saaty, 1987). As a result of these comparisons, the direct relationship matrix is obtained using Equation (1).

$$\text{aij} = \frac{1}{H}\sum_{k=1}^{n} X_{ij}^{k} \quad (1)$$

Here,

H = number of experts

n = number of factors

k = number of survey participants

X_{ij}^{k} = the degree of influence of criterion i on criterion j regarding the k-th response (where 'criterion' refers to the topic in this study).

In the relationship matrix created using Equation (1), the alternatives are represented in the rows, and the criteria are represented in the columns.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2j} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mj} & \cdots & a_{mn} \end{bmatrix}$$

Step 2: Normalization of the Direct Relationship Matrix

The direct relationship matrix is normalized by dividing it by the largest value among the sums of its rows and columns (Equations 2 and 3). The normalized direct relationship matrix is then calculated (Altuntas & Gok, 2021).

$$S = \max\left(\max_{1<i<n} \sum_{j=1}^{n} a_{ij},\ \max_{1<j<n} \sum_{i=1}^{n} a_{ij}\right) \quad (2)$$

$$D \text{ (Direct Relationship Matrix)} = \frac{A}{S} \quad (3)$$

Step 3: Total Relationship Matrix (T): The Total Relationship Matrix (T) is calculated using Equation (4):

T = D (I - D)-1 (4)

D: Direct Relationship Matrix

I: Represents the identity matrix.

Where:

D: Direct Relationship Matrix

I: Identity Matrix

Step 4: Identification of Influencing and Influenced Criteria Groups

The row total (D) obtained from the total relationship matrix represents the extent to which a criterion influences other criteria directly or indirectly, while the column total (R) indicates the extent to which a criterion is influenced by other criteria directly or indirectly (Aldowah, Al-Samarraie, Alzahrani & Alalwan, 2020). Criteria with a positive D-R value have a greater impact on other criteria and are considered to have higher priority in the system; these criteria are typically referred to as "dispatchers." Conversely, criteria with a negative D-R value are more influenced by other criteria and are evaluated as lower-priority criteria, often referred to as "receivers." Conversely, the D+R value signifies the comprehensive extent to which a criterion interrelates with other criteria. Criteria with elevated D+R values demonstrate robust interactions with other criteria within the system, while criteria with diminished D+R values exhibit weaker relationships (Altuntas & Gok, 2021; Chen, 2016; Liou, Tzeng & Chang, 2007; Yang, Shieh, Leu & Tzeng, 2008). Consequently, D-R and D+R values assume a pivotal role in the analysis of the importance levels and interrelationships of the criteria within the system.

Step 5: Threshold Value and Diagram Creation

In order to ascertain the effects between the criteria, an interaction diagram is created. This diagram is obtained by showing the points (D+R, D-R) on a coordinate plane with D+R on the horizontal axis and D-R on the vertical axis. In the creation of the influence directional graph diagram, a threshold value should be determined. As outlined in step 1, this threshold value can be defined by the relevant decision makers, or alternatively, the average value of the T matrix can be used as a threshold value (Tsai & Chou, 2009; Tzeng, Chiang & Li, 2007; Wu & Lee, 2007).

FINDINGS

The findings of this study are comprised of two sections. Firstly, the chemistry questions in the TYT and AYT tests in YKS in 2018-2024 were categorized according to the subjects of the 2018 Secondary School Chemistry Curriculum. In the second section, the relationships among the classified topics were analyzed following the steps defined by the DEMATEL method.

Classification of Exam Questions by Topics

Distribution of Chemistry Questions in the TYT Test by Units and Topics

The chemistry questions included in the TYT tests of the YKS conducted by ÖSYM between 2018 and 2024 were classified according to the topics in the 2018 Secondary School Chemistry Curriculum (Table 4). The first column of the table lists the unit names, while the subsequent columns provide the topic names, exam years, and total number of questions, respectively.

Table 4. Distribution of Chemistry Questions in the TYT Exam by Units and Topics

Unit Name	Topic Name	Year							Total Question Count
		2018	2019	2020	2021	2022	2023	2024	
TYTK1 Chemistry as a Science	From Alchemy to Chemistry	0	0	0	0	0	0	0	6
	Chemistry Disciplines and Fields of Study	0	0	0	0	1	0	0	
	The Symbolic Language of Chemistry	0	1	0	1	0	1	0	
	Occupational Health and Safety in Chemical Applications	0	0	1	0	0	0	1	
TYTK2 Atom and Periodic System	Atomic Models	1	0	0	0	0	0	1	9
	Structure of the Atom	0	1	0	0	0	1	0	
	Periodic Table	1	1	1	1	1	0	0	
TYTK3 Interactions Among Chemical Species	Chemical Species	0	0	0	0	0	0	0	8
	Classification of Interactions Among Chemical Species	1	0	1	0	0	0	0	
	Strong Interactions	1	0	0	1	1	0	0	
	Weak Interactions	0	1	0	0	0	0	1	
	Physical and Chemical Changes	0	0	0	0	0	1	0	
TYTK4 States of Matter	Physical States of Matter	0	0	0	0	0	0	0	6
	Solids	0	0	0	0	0	0	0	
	Liquids	1	0	1	1	1	0	1	
	Gases	0	0	0	0	0	1	0	
	Plasma	0	0	0	0	0	0	0	
Nature and Chemistry	Water and Life	0	0	0	0	0	0	0	0
	Environmental Chemistry	0	0	0	0	0	0	0	
TYTK5 Fundamental Laws of Chemistry and Chemical Calculations	Fundamental Laws of Chemistry	0	0	0	0	1	0	0	4
	Mole Concept	0	0	0	0	0	1	1	
	Chemical Reactions and Equations	0	0	0	0	0	0	0	
	Calculations in Chemical Reactions	0	0	0	1	0	0	0	
TYTK6 Mixtures	Homogeneous and Heterogeneous Mixtures	1	1	1	1	1	0	1	7

	Separation and Purification Techniques	0	0	0	0	0	1	0	
TYTK7 Acids, Bases, and Salts	Acids and Bases	0	0	0	0	1	1	0	7
	Reactions of Acids and Bases	0	1	2	1	0	0	1	
	Acids and Bases in Daily Life	0	0	0	0	0	0	0	
	Salts	0	0	0	0	0	0	0	
TYTK8 Chemistry Everywhere	Common Everyday Chemicals	1	1	0	0	0	0	0	2
	Foods	0	0	0	0	0	0	0	

When evaluating how the topics from the 2018 Secondary School Chemistry Curriculum were addressed in the TYT exam and which topics were prioritized based on the data in the table, it is observed that TYTK2 Atom and Periodic System (9 questions), TYTK3 Interactions Among Chemical Species (8 questions), and TYTK6 Mixtures (7 questions) consistently appeared in the exams each year. While TYTK7 Acids, Bases, and Salts (7 questions), TYTK1 Chemistry as a Science (6 questions), and TYTK4 States of Matter (6 questions) did not appear every year, they are among the topics that were predominantly covered overall. In contrast, TYTK5 Fundamental Laws of Chemistry and Chemical Calculations (4 questions) and TYTK8 Chemistry Everywhere (2 questions) were less frequently addressed in the exams. Despite being included in the 2018 Secondary School Chemistry Curriculum, the "Nature and Chemistry" unit was not represented in any of the chemistry questions in the Basic Proficiency Test (TYT) of the Higher Education Institutions Exam (YKS) conducted between 2018 and 2024.

Distribution of Chemistry Questions in the AYT Exam by Units and Topics

The chemistry questions included in the AYT exam, part of the YKS conducted by ÖSYM between 2018 and 2024, were classified according to the topics of the 2018 Secondary School Chemistry Curriculum (Table 5). The first column of the table lists the unit names, while the subsequent columns present the topic areas, exam years, and total number of questions, respectively.

Table 5. Distribution of Chemistry Questions in the AYT Exam by Units and Topics

Unit Name	Topic Name	Year							Total
		2018	2019	2020	2021	2022	2023	2024	Question Count
AYTK1 Modern Atomic Theory	Quantum Model of the Atom	0	1	2	0	1	1	1	7
	Periodic Table and Electron Configurations	0	0	0	0	0	0	0	
	Periodic Properties	1	0	0	0	0	0	0	
	Identifying Elements	0	0	0	0	0	0	0	
	Oxidation States	0	0	0	0	0	0	0	
AYTK2 Gases	Properties of Gases and Gas Laws	0	0	0	0	0	0	0	10
	Ideal Gas Law	0	0	0	0	1	1	0	
	Kinetic Theory of Gases	1	1	0	0	0	1	1	
	Gas Mixtures	0	1	1	1	0	0	0	
	Real Gases	1	0	0	0	0	0	0	
AYTK3 Liquid Solutions and Solubility	Solvent-Solute Interactions	0	0	0	0	0	0	0	13
	Concentration Units	1	0	1	1	1	2	1	
	Colligative Properties	0	1	1	0	1	0	1	
	Solubility	1	0	0	1	0	0	0	
	Factors Affecting Solubility	0	0	0	0	0	0	0	
AYTK4 Energy in Chemical Reactions	Heat Changes in Reactions	0	0	0	0	0	0	0	6
	Enthalpy of Formation	0	1	1	1	1	1	1	
	Bond Energies	0	0	0	0	0	0	0	
	Additivity of Reaction Heats	0	0	0	0	0	0	0	
AYTK5 Reaction Rates in Chemical Reactions	Reaction Rates	0	1	1	0	1	1	0	7
	Factors Affecting Reaction Rates	1	0	0	1	0	0	1	
AYTK6 Equilibrium in Chemical Reactions	Chemical Equilibrium	0	0	0	0	1	0	0	13
	Factors Affecting Equilibrium	0	0	1	1	0	1	1	
	Aqueous Solution Equilibria	1	2	1	1	1	1	1	
AYTK7 Chemistry and Electricity	Electric Current in Redox Reactions	0	0	1	1	0	0	0	17
	Electrodes and Electrochemical Cells	1	0	1	1	1	0	0	
	Electrode Potentials	1	0	1	0	1	2	1	
	Electricity Generation from Chemicals	0	0	0	0	0	0	0	
	Electrolysis	0	1	0	1	0	1	1	
	Corrosion	0	1	0	0	0	0	0	
AYTK8 Introduction to Carbon Chemistry	Inorganic and Organic Compounds	0	0	0	0	0	0	0	6
	Empirical Formula and Molecular Formula	0	0	0	0	1	0	0	
	Carbon in Nature	0	1	0	0	0	1	0	
	Lewis Structures	0	0	0	0	0	0	1	
	Hybridization and Molecular Geometries	0	0	1	1	0	0	0	
	Hydrocarbons	2	2	0	1	0	0	1	12

AYTK9 Organic Compounds	Functional Groups	1	0	0	0	0	0	0	
	Alcohols	0	0	0	1	0	0	0	
	Ethers	0	0	0	0	0	0	0	
	Carbonyl Compounds	0	0	0	0	1	0	0	
	Carboxylic Acids	1	0	0	0	0	0	1	
	Esters	0	0	0	0	1	0	0	
Energy Resources and Scientific Advances	Fossil Fuels	0	0	0	0	0	0	0	0
	Alternative Energy Sources	0	0	0	0	0	0	0	
	Sustainability	0	0	0	0	0	0	0	
	Nanotechnology	0	0	0	0	0	0	0	

When examining the distribution of questions in the AYT chemistry test by units and topics over the years, as presented in Table 5, the most frequently asked topics are, in order: AYTK7 Chemistry and Electricity (17 questions), AYTK3 Liquid Solutions and Solubility (13 questions), AYTK6 Equilibrium in Chemical Reactions (13 questions), AYTK9 Organic Compounds (12 questions), and AYTK2 Gases (10 questions).The topics with fewer questions are, in order: AYTK1 Modern Atomic Theory (7 questions), AYTK5 Reaction Rates in Chemical Reactions (7 questions), AYTK4 Energy in Chemical Reactions (6 questions), and AYTK8 Introduction to Carbon Chemistry (6 questions). It is also observed that no questions were included on the topic of Energy Resources and Scientific Advances in the chemistry section of the exam.

Step 1: Construction of the Direct Relationship Matrix

In the classification of chemistry questions from the TYT test, conducted as part of the YKS exam by ÖSYM between 2018 and 2024, according to the topics of the 2018 Secondary School Chemistry Curriculum, no questions were asked in the chemistry section of the TYT Science test for the topic areas within the Nature and Chemistry unit. Therefore, this unit was excluded from the Direct Relationship Matrix. The relationships between the topics within the units were analyzed through pairwise comparisons, using the values provided in the last column of Table 4, resulting in the direct-relationship matrix presented in Table 6.

Table 6. The initial Direct-relation Matrix with Using Pairwise Comparison for TYT Chemistry Questions by Unit Topics

Unit Topics	TYTK1	TYTK2	TYTK3	TYTK4	TYTK5	TYTK6	TYTK7	TYTK8
TYTK1	0,000	0,667	0,750	1,000	1,500	0,857	0,857	3,000
TYTK2	1,500	0,000	1,125	1,500	2,250	1,286	1,286	4,500
TYTK3	1,333	0,889	0,000	1,333	2,000	1,143	1,143	4,000
TYTK4	1,000	0,667	0,750	0,000	1,500	0,857	0,857	3,000
TYTK5	0,667	0,444	0,500	0,667	0,000	0,571	0,571	2,000
TYTK6	1,167	0,778	0,875	1,167	1,750	0,000	1,000	3,500
TYTK7	1,167	0,778	0,875	1,167	1,750	1,000	0,000	3,500
TYTK8	0,333	0,222	0,250	0,333	0,500	0,286	0,286	0,000

Step 2: Normalization of the Direct Relationship Matrix

The normalised direct relationship matrix (Table 7) was obtained by dividing the direct relationship matrix by the largest value between the sum of the rows and columns of the matrix (Equation 2 and Equation 3) (Altuntas & Gok, 2021).

$$S = \max\left(\max_{1<i<n} \sum_{j=1}^{n} a_{ij} , \max_{1<j<n} \sum_{i=1}^{n} a_{ij}\right) \quad (2)$$

$$D \text{ (Direct Relationship Matrix)} = \frac{A}{S} \quad (3)$$

Table 7. The Normalized Direct Relationship Matrix

Unit Topics	TYTK1	TYTK2	TYTK3	TYTK4	TYTK5	TYTK6	TYTK7	TYTK8
TYTK1	0,000	0,028	0,032	0,043	0,064	0,036	0,036	0,128
TYTK2	0,064	0,000	0,048	0,064	0,096	0,055	0,055	0,191
TYTK3	0,057	0,038	0,000	0,057	0,085	0,049	0,049	0,170
TYTK4	0,043	0,028	0,032	0,000	0,064	0,036	0,036	0,128
TYTK5	0,028	0,019	0,021	0,028	0,000	0,024	0,024	0,085
TYTK6	0,050	0,033	0,037	0,050	0,074	0,000	0,043	0,149
TYTK7	0,050	0,033	0,037	0,050	0,074	0,043	0,000	0,149
TYTK8	0,014	0,009	0,011	0,014	0,021	0,012	0,012	0,000

Step 3: Construction of the Total Relationship Matrix

The Normalized Direct Relationship Matrix obtained in Table 7 is first subtracted from the identity matrix. The total relationship matrix is then calculated by multiplying the inverse of the resulting matrix with the normalized direct relationship matrix. The resulting matrix is presented in Table 8.

Table 8.The Total Relation Matrix

Unit Topics	TYTK1	TYTK2	TYTK3	TYTK4	TYTK5	TYTK6	TYTK7	TYTK8
TYTK1	0,017	0,039	0,044	0,058	0,087	0,05	0,05	0,174
TYTK2	0,087	0,017	0,065	0,087	0,131	0,075	0,075	0,262
TYTK3	0,078	0,052	0,017	0,078	0,116	0,066	0,066	0,233
TYTK4	0,058	0,039	0,044	0,017	0,087	0,05	0,05	0,174
TYTK5	0,039	0,026	0,029	0,039	0,017	0,033	0,033	0,116
TYTK6	0,068	0,045	0,051	0,068	0,102	0,017	0,058	0,203
TYTK7	0,068	0,045	0,051	0,068	0,102	0,058	0,017	0,203
TYTK8	0,019	0,013	0,015	0,019	0,029	0,017	0,017	0,017

Step 4: Identification of Influencing and Influenced Criterion Groups

In order to ascertain the relationships between the criteria, 'D' vectors were calculated from row sums and 'R' vectors were calculated from column sums (Aldowah, Al-Samarraie, Alzahrani & Alalwan, 2020). With the values of D and R vectors, D+R and D-R values were calculated (see Table 9).

Table 9. Importance Levels of TYT Chemistry Topics and Their Influence on Each Other

Unit Topics	D	R	D+R	D-R	Level of Influence
TYTK1 Chemistry as a Science	0,519	0,434	0,953	0,085	Influencing
TYTK2 Atom and Periodic System	0,799	0,276	1,075	0,523	Influencing
TYTK3 Interactions Among Chemical Species	0,706	0,315	1,021	0,39	Influencing
TYTK4 States of Matter Nature and Chemistry	0,519	0,434	0,953	0,085	Influencing
TYTK5 Fundamental Laws of Chemistry and Chemical Calculation	0,332	0,671	1,004	-0,339	**Influenced**
TYTK6 Mixtures	0,612	0,366	0,978	0,246	Influencing
TYTK7 Acids, Bases, and Salts	0,612	0,366	0,978	0,246	Influencing
TYTK8 Chemistry Everywhere	0,146	1,383	1,529	-1,238	**Influenced**

In Table 9, the D+R and D-R values were calculated to analyze the relationships between the topics. The D+R values obtained indicate a positive relationship between the topics, with Chemistry is Everywhere (TYTK8), Atomic Structure and Periodic Table (TYTK2), Interactions between Chemical Species (TYTK3) and Fundamental Laws of Chemistry and Chemical Calculations (TYTK5) demonstrating a higher degree of relatedness to other topics. Negative values of D-R indicate lower priority and greater susceptibility to influence from other criteria. In this context, it was determined that the topics of TYTK8 Chemistry is Everywhere and TYTK5 Basic Laws of Chemistry and Chemical Calculations were more significantly impacted than other topics. Conversely, positive D-R values indicate topics with higher priority and impact level. In this particular context, it was determined that the topics of TYTK2 The Structure of the Atom and Periodic Table, TYTK3 Interactions between Chemical Species and TYTK6 Acids, Bases and Salts were more influential than other topics.

Step 5: Determination of the Threshold Value and Diagram Construction

In this study, the threshold value was determined as 0,066 by calculating the average of the total relationship matrix. In Table 8, values greater than the threshold are highlighted in bold. Based on the values exceeding the threshold in Table 8, the interactions between the topics are illustrated in Figure 1.

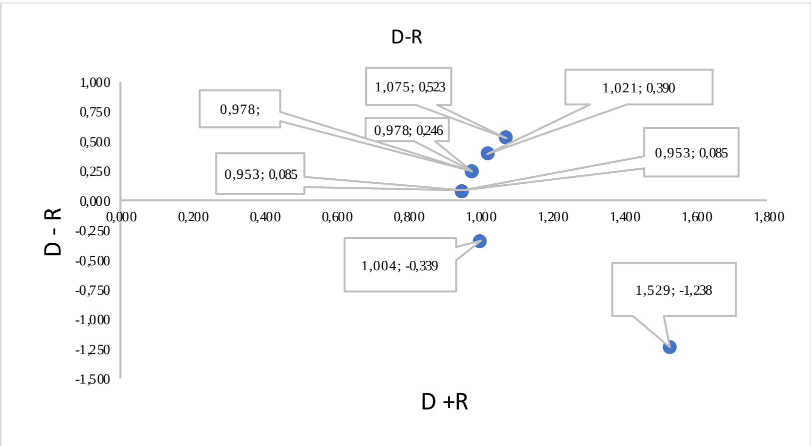

Figure 1. Influencing-Influenced Graph Diagram of TYT Chemistry Topics

AYT Science Test – Chemistry Section

Step 1: Construction of the Direct Relationship Matrix

In the classification of chemistry questions from the AYT test conducted by ÖSYM between 2018-2024 according to the topics in the 2018 Secondary School Chemistry Curriculum, the unit "Energy Resources and Scientific Developments" was excluded from the direct relationship matrix because no questions related to this unit were included in the chemistry section of the AYT Science Test. The relationships between the unit topics were determined using pairwise comparisons based on the values in the final column of Table 5, resulting in the Direct Relationship Matrix presented in Table 10.

Table 10. The Initial Direct-Relation Matrix With Using Pairwise Comparison for AYT Chemistry Questions by Unit Topics

Unit Topics	AYTK1	AYTK2	AYTK3	AYTK4	AYTK5	AYTK6	AYTK7	AYTK8	AYTK9
AYTK1	0,000	0,700	0,538	1,167	1,000	0,538	0,412	1,167	0,583
AYTK2	1,429	0,000	0,769	1,667	1,429	0,769	0,588	1,667	0,833
AYTK3	1,857	1,300	0,000	2,167	1,857	1,000	0,765	2,167	1,083
AYTK4	0,857	0,600	0,462	0,000	0,857	0,462	0,353	1,000	0,500
AYTK5	1,000	0,700	0,538	1,167	0,000	0,538	0,412	1,167	0,583
AYTK6	1,857	1,300	1,000	2,167	1,857	0,000	0,765	2,167	1,083
AYTK7	2,429	1,700	1,308	2,833	2,429	1,308	0,000	2,833	1,417
AYTK8	0,857	0,600	0,462	1,000	0,857	0,462	0,353	0,000	0,500
AYTK9	1,714	1,200	0,923	2,000	1,714	0,923	0,706	2,000	0,000

Step 2: Normalization of the Direct Relationship Matrix

The direct relationship matrix was normalized by dividing each value in the matrix by the maximum of the row and column sums (Equations 2 and 3). This process resulted in the Normalized Direct Relationship Matrix (Table 11).

Table 11. The Normalized Direct Relationship Matrix

Unit Topics	AYTK1	AYTK2	AYTK3	AYTK4	AYTK5	AYTK6	AYTK7	AYTK8	AYTK9
AYTK1	0,000	0,043	0,033	0,072	0,062	0,033	0,025	0,072	0,036
AYTK2	0,088	0,000	0,047	0,103	0,088	0,047	0,036	0,103	0,051
AYTK3	0,114	0,080	0,000	0,133	0,114	0,062	0,047	0,133	0,067
AYTK4	0,053	0,037	0,028	0,000	0,053	0,028	0,022	0,062	0,031
AYTK5	0,062	0,043	0,033	0,072	0,000	0,033	0,025	0,072	0,036
AYTK6	0,114	0,080	0,062	0,133	0,114	0,000	0,047	0,133	0,067
AYTK7	0,149	0,105	0,080	0,174	0,149	0,080	0,000	0,174	0,087
AYTK8	0,053	0,037	0,028	0,062	0,053	0,028	0,022	0,000	0,031
AYTK9	0,105	0,074	0,057	0,123	0,105	0,057	0,043	0,123	0,000

Step 3: Construction of the Total Relationship Matrix

The Normalized Direct Relationship Matrix obtained in Table 11 is first subtracted from the identity matrix. The total relationship matrix is then calculated by multiplying the inverse of the resulting matrix with the normalized direct relationship matrix. The resulting matrix is presented in Table 12.

Table 12.The Total Relation Matrix

Unit Topics	AYTK1	AYTK2	AYTK3	AYTK4	AYTK5	AYTK6	AYTK7	AYTK8	AYTK9
AYTK1	0,056	0,080	0,061	0,133	0,114	0,061	0,047	0,133	0,067
AYTK2	0,163	0,056	0,088	0,190	0,163	0,088	0,067	0,190	0,095
AYTK3	0,212	0,148	0,056	0,247	0,212	0,114	0,087	0,247	0,124
AYTK4	0,098	0,068	0,053	0,056	0,098	0,053	0,040	0,114	0,057
AYTK5	0,114	0,080	0,061	0,133	0,056	0,061	0,047	0,133	0,067
AYTK6	0,212	0,148	0,114	0,247	0,212	0,056	0,087	0,247	0,124
AYTK7	0,277	0,194	0,149	0,323	0,277	0,149	0,056	0,323	0,162
AYTK8	0,098	0,068	0,053	0,114	0,098	0,053	0,040	0,056	0,057
AYTK9	0,196	0,137	0,105	0,228	0,196	0,105	0,081	0,228	0,056

Step 4: Identification of Influencing and Influenced Criterion Groups

To determine the relationships between the criteria, the row sums were used to calculate the "D" vector, while the column sums were used to calculate the "R" vector (Aldowah, Al-Samarraie, Alzahrani & Alalwan, 2020). Using the values of the D and R vectors, the D+R and D-R values were also calculated and are presented in Table 13.

Table 13. Importance Levels of AYT Chemistry Topics and Their Influence on Each Other

Unit Name	D	R	D+R	D-R	Level of Influence
AYTK1 Modern Atomic Theory	0,753	1,425	2,178	-0,673	**Influenced**
AYTK2 Gases	1,100	0,980	2,081	0,120	Influencing
AYTK3 Liquid Solutions and Solubility	1,448	0,741	2,189	0,707	Influencing
AYTK4 Energy in Chemical Reactions	0,637	1,673	2,310	-1,036	**Influenced**
AYTK5 Reaction Rates in Chemical Reactions	0,753	1,425	2,178	-0,673	**Influenced**
AYTK6 Equilibrium in Chemical Reactions	1,448	0,741	2,189	0,707	Influencing
AYTK7 Chemistry and Electricity	1,911	0,553	2,464	1,358	Influencing
AYTK8 Introduction to Carbon Chemistry	0,637	1,673	2,310	-1,036	**Influenced**
AYTK9 Organic Compounds	1,332	0,807	2,139	0,525	Influencing

According to the results obtained in Table 13, the highest D+R value (2,464) indicates that the topic AYTK7 Chemistry and Electricity has the greatest interaction with other topics. The lowest D+R value (2, 081) indicates that the subject of AYTK2 Gases has less interaction with other subjects. On the other hand, it is seen that AYTK7 Chemistry and Electricity with the highest D-R value (1,358) is more effective on other subjects and AYTK4 Energy in Chemical Reactions and AYTK8 Introduction to Carbon Chemistry with the lowest D-R value (-1,036) are more affected by all other subjects.

Step 5: Determination of the Threshold Value and Diagram Construction

In this study, the threshold value was determined as 0,124 by calculating the average of the total relationship matrix. In Table 12, values exceeding the threshold are highlighted in bold. Based on the values above the threshold in Table 13, the interactions between the topics are illustrated in Figure 2.

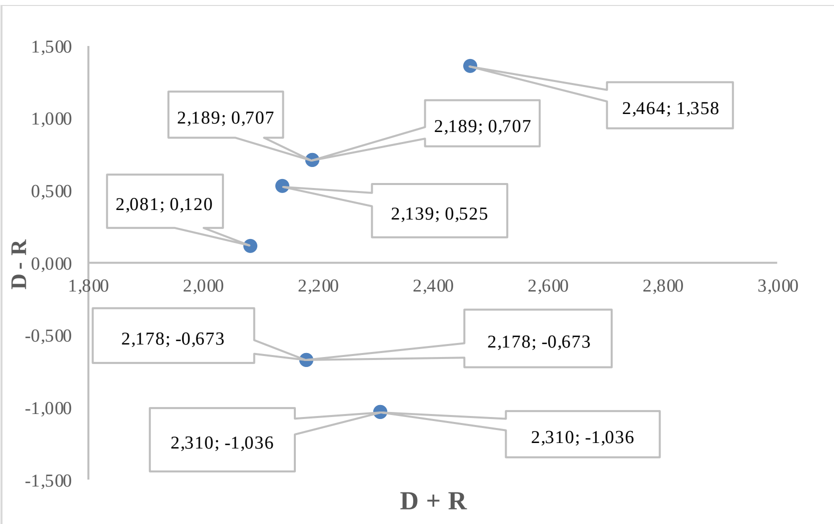

Figure 2. Influencing-Influenced Graph Diagram of AYT Chemistry Topics

RESULT, DISCUSSION AND RECOMMENDATIONS

In this study, the chemistry questions in the TYT (Basic Proficiency Test) and AYT (Field Proficiency Test) applied within the scope of YKS (Higher Education Institutions Examination) between 2018-2024 were classified according to the 2018 chemistry curriculum, and the relationships between the subjects were analysed by DEMATEL method. The analysis revealed that the subject distribution of chemistry questions in TYT and AYT tests according to years was not homogeneous. In the TYT test, it was determined that TYTK2 Atom and Periodic System, TYTK3 Interactions between Chemical Species and TYTK6 Mixtures Unit topics were regularly included in the exams on an annual basis. In contrast, it was observed that TYTK7 Acids, Bases and Salts, TYTK1 Science of Chemistry and TYTK4 States of Matter were not included on a regular basis in the exam, yet their collective weight in the examination was significant. In addition, it was found that the topics of TYTK5 Basic Laws of Chemistry and Chemical Calculations and TYTK8 Chemistry Everywhere were less included in the TYT Chemistry test.

Despite being included in the 2018 Chemistry curriculum, it was determined that no question from the Nature and Chemistry unit was included in the Chemistry section of the Basic Proficiency Test (TYT) of the Higher Education Institutions Examination (YKS) conducted between 2018 and 2024. In the study (Gacanoğlu & Nakiboğlu, 2022), in which chemistry questions asked within the scope of TYT and AYT were evaluated in terms of the gains of the 2018 Secondary Education Chemistry Curriculum and the subject content validity of the exams, it was concluded that there were no questions from the Nature and Chemistry unit between 2019-2021.

Analyzing the unit and subject distribution of the questions in the higher education examination (YKS) in the field of chemistry between 2018 and 2024, it was found that the subjects in the units AYTK7 Chemistry and Electricity, AYTK3 Liquid Solutions and Solubility, AYTK6 Equilibrium in Chemical Reactions, AYTK9 Organic Compounds and AYTK2 Gases gained more weight and the questions related to these units were more intensive in the examination. On the other hand, the number of questions in AYTK1 Modern Atomic Theory, AYTK5 Rates of Chemical Reactions, AYTK4 Energy in Chemical Reactions, and AYTK8 Introduction to Carbon Chemistry were relatively lower. On the other hand, it was noted that the Energy Sources and Scientific Developments unit in the 2018 chemistry curriculum was not included in the AYT chemistry tests between 2018-2024.

Similarly, Gacanoğlu and Nakiboğlu (2022) reported that there were no questions from the energy resources and scientific development unit in 2019-2021. This indicates that the weight of some topics in the exam is not in line with their theoretical importance, which is emphasized in the curriculum. In both the AYT and the TYT, this discrepancy between the frequency with which some topics are covered in the exam and their theoretical importance in the curriculum is noteworthy. As emphasized in the study of Gacanoğlu and Nakiboğlu (2022), the fact that no questions on energy resources and scientific developments were asked in the exams held in 2018-2024 indicates that the exams are problematic in terms of subject content validity.

The importance levels of the TYT chemistry topics and their interrelationships were analyzed using the DEMATEL method, and the influencing and influenced roles, importance levels, and influence levels of the topics were determined. The results provide an important framework for understanding the relationship between topics in the chemistry curriculum and which topics are more critical for exam success. The topics with positive (D-R) values were found to have a strong influence on the other topics, such as TYTK2 Atomic Structure and Periodic Table, TYTK3 Interactions between Chemical Species, TYTK6 Acids, Bases and Salt, and TYTK7 Mixtures. It is understood that these topics are among the basic building blocks of the discipline of chemistry and are critical to the understanding of other topics. On the other hand, the topics with negative (D-R) values, namely TYTK8 Chemistry is Everywhere and TYTK5 Basic Laws of Chemistry and Chemical Calculations, which include the basic principles of chemistry, were found to be strongly influenced by other topics and assumed a more information-receiving role. This underscores the need to get the basics right in order to understand these topics better.

These data, obtained by analyzing the importance levels of YKS AYT Chemistry topics and the influence relationships between topics using DEMATEL method, are important in terms of understanding the effects of topics in AYT Chemistry curriculum on each other and which topics are more information providers (influencing) or information receivers (influenced). In the AYT Chemistry curriculum, AYTK7 Chemistry and Electricity, AYTK4 Energy in Chemical Reactions, AYTK8 Introduction to Carbon Chemistry, AYTK3 Liquid Solutions and Solubility, AYTK6 Equilibrium in Chemical Reactions, and AYTK2 Gases have high (D+R) values. This indicates that these topics are both impressive and have strong connections with other topics and play a central role in the curriculum. High total interaction scores indicate that these topics form a strong link as both information providers and information receivers. AYTK7 Chemistry and Electricity, AYTK6 Equilibrium in Chemical Reactions, AYTK3 Liquid Solutions and Solubility, and AYTK9 Organic Compounds, which have positive (D-R) values, stand out as key topics that play an influential role in the AYT chemistry curriculum. These topics are critical to the understanding and learning other topics. On the other hand, AYTK8 Introduction to Carbon Chemistry, AYTK4 Energy in Chemical Reactions, AYTK1 Modern Atomic Theory, and AYTK5 Rate of Chemical Reactions, which have negative (D-R) values, are in the Information Receptor category and are strongly influenced by other topics. These topics are considered to be among those that should be learned with the support of basic knowledge. In particular, AYTK2 Gases plays an important role in the curriculum by being among the influencing topics, although it has a relatively lower total interaction value compared to other topics. This analysis provides a comprehensive framework to better understand the importance and interrelationships of topics in the chemistry curriculum.

Suggestions, Limitations and Future studies

Recommendations

When the study is evaluated in general terms, by determining the distribution of the questions in the TYT and AYT Chemistry test according to the units and subjects by years, it evaluates the compatibility between the exam content and the chemistry curriculum, providing academically significant information to understand in which areas students are expected to have more knowledge and to optimize teaching strategies. In light of the findings obtained from this study, the following recommendations can be made for students preparing for the Higher Education Institutions Examination (Higher Education Institutions Examination), instructors and institutions preparing educational programmes:

Firstly, an evaluation of exam strategies can provide valuable insights into which subjects students should prioritise in their exam preparation. It is particularly recommended that students focus on subjects deemed critical to enhancing exam success, dedicating more attention to frequently asked topics during the preparation process.

Secondly, when the contribution of the research to curriculum development studies is evaluated, it can be regarded as a significant source for understanding the effects of the subjects in the chemistry curriculum on exam success and their relationships with each other. Furthermore, it can provide educators with the opportunity to make improvements in the curriculum by using these data. Institutions that prepare chemistry education programmes should make updates and adjustments in a way to give more space to the subjects that stand out in YKS exams according to the priorities revealed by DEMATEL analysis.

Thirdly, lecturers working in the field of chemistry education are recommended to conduct studies on the applicability of DEMATEL analysis in different subjects in other academic studies to be conducted in the field of chemistry education.

Fourthly, the DEMATEL analysis can serve as a model for the evaluation of curricula in other disciplines.

The limitations of the study are as follows:

The present study has been unable to ascertain the causal relationships between the topics of chemistry questions in TYT and AYT in the YKS exam, determine which topic is prioritised and important compared to the others, and identify which topic is the affecting/influenced topic. The DEMATEL method has been employed to measure the latter, but the study has not been able to do so completely. The primary objective of this study is to demonstrate the methodological feasibility of identifying causal relationships between chemistry questions in TYT and AYT in the YKS exam, based on unit topics, and to evaluate the relative prioritization of these topics. It should be noted that the analyses were conducted exclusively using questions published by ÖSYM, while textbooks and student experiences were not considered. The enhancement of content validity for the proposed method may be achieved through the modelling of sub-subjects within the units. Nevertheless, the issue arising from the absence of questions in certain subject areas that constitute the foundation of TYT and AYT chemistry questions must be addressed. In the DEMATEL technique, the level of importance of each criterion relative to the others is determined through the formation of pairwise comparison matrices. For instance, if pairwise comparisons are made for subject areas not included in the exams ($a/0 \neq 0$), this is not possible since it is 'undefined'. This constraint can be overcome by using the Z-score standardization transformation developed by Zhang, Wang, Li and Xu (2014) in the case of zero or negative values in the decision matrix for the multi criteria decision making problem. In addition, this study employed the DEMATEL method, a Multi-Criteria Decision-Making method, yet the impact of divergent analysis methods on outcomes was not investigated.

Proposals for Subsequent Research

1. The present study encompasses the years from 2018 to 2024, with the option of extending its temporal scope to encompass a more extensive period and examining it across different timeframes, beyond the designated YKS period.

2. In addition to DEMATEL, alternative multi-criteria decision-making techniques, such as AHP, ANP and TOPSIS, can be utilized to evaluate the relationships between subjects from diverse perspectives.

3. A further avenue for research would be to compare the distribution of topics and the relationships between topics with those of other science courses, such as physics and biology.

Declarations

Conflict of Interest

No potential conflicts of interest were disclosed by the author(s) with respect to the research, authorship, or publication of this article.

Ethics Approval

In this study, the rules specified in the 'Directive on Scientific Research and Publication Ethics of Higher Education Institutions' were followed. In addition, none of the actions specified under the heading 'Actions Contrary to Scientific Research and Publication Ethics' of the directive have been carried out.

The study is based on information field research studies in open access sources. The research does not include personal information and experimentation process. Therefore, the research is within the scope of studies that do not require ethics committee permission.

Hereby, we as the authors consciously assure that for the manuscript the following is fulfilled:

- This material is the authors' own original work, which has not been previously published elsewhere.
- The paper reflects the authors' own research and analysis in a truthful and complete manner.
- The results are appropriately placed in the context of prior and existing research.
- All sources used are properly disclosed.

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