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Determining Pre-Service Science Teachers' Conceptual Understanding of Fundamental Chemistry Concept

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ABSTRACT

The primary goal of contemporary science education is to cultivate individuals capable of critical thinking and scientific reasoning. Within this framework, conceptual understanding in chemistry extends beyond algorithmic problem solving. It requires the ability to explain, relate, and justify chemical concepts across different contexts. The present study aimed to examine the levels of conceptual understanding of fundamental chemistry concepts among second-, third-, and fourth-year pre-service science teachers and to determine whether these levels differ by grade level. The study was conducted using a quantitative, cross-sectional survey design. Data were collected from 83 pre-service science teachers enrolled at a public university through the Chemistry Concept Reasoning Test (CCRT). Descriptive statistics and non-parametric analyses were employed to analyze the data. The findings revealed that the overall mean score was 9.30 (SD= 2.73) out of a possible 38.5 points, corresponding to approximately 24% of the total score and indicating a low level of conceptual achievement. The Kruskal–Wallis H test showed no statistically significant difference among grade levels (H(2)=2.632, p= .268), and the effect size was negligible (η^2_h = .008). These results suggest that exposure to chemistry coursework across grade levels does not automatically lead to meaningful improvements in reasoning-based conceptual understanding. The study highlights the need for concept-based, model-oriented instructional and assessment practices in teacher education programs.

Keywords: Chemistry education, conceptual understanding, fundamental chemistry concepts, pre-service science teacher, reasoning

Fen Bilgisi Öğretmen Adaylarının Temel Kimya Kavramları İle İlgili Bilgi ve Anlayışlarının Belirlenmesi

Bilgi

**Sorumlu yazar*

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ÖZ

Çağdaş fen eğitiminin temel amacı, eleştirel düşünebilen ve bilimsel akıl yürütme becerilerine sahip bireyler yetiştirmektir. Bu bağlamda kimyada kavramsal anlama, algoritmik problem çözmenin ötesine geçmektedir. Kavramsal anlama; kimyasal kavramların farklı bağlamlarda açıklanabilmesini, ilişkilendirilebilmesini ve gerekçelendirilebilmesini gerektirmektedir. Bu çalışmada, fen bilgisi öğretmenliği lisans programında öğrenim gören ikinci, üçüncü ve dördüncü sınıf öğretmen adaylarının temel kimya kavramlarına ilişkin kavramsal anlayış düzeylerinin incelenmesi ve bu düzeylerin sınıf düzeyine göre farklılaşıp farklılaşmadığının belirlenmesi amaçlanmıştır. Araştırma nicel, kesitsel tarama deseninde yürütülmüştür. Veriler, bir devlet üniversitesinde öğrenim gören 83 öğretmen adayından Kimya Kavramları Akıl Yürütme Testi (CCRT) aracılığıyla toplanmıştır. Verilerin analizinde betimsel istatistikler ve non-parametrik analizler kullanılmıştır. Bulgular, öğretmen adaylarının testten aldıkları ortalama puanın 38.5 üzerinden 9.30 (SS = 2.73) olduğunu ve bu değerin toplam puanın yaklaşık %24'üne karşılık geldiğini göstermiştir. Bu durum, kavramsal başarı düzeyinin düşük olduğunu ortaya koymaktadır. Kruskal–Wallis H testi sonuçları, sınıf düzeyleri arasında istatistiksel olarak anlamlı bir fark bulunmadığını göstermiştir (H(2)=2.632, p= .268). Etki büyüklüğü değeri ise ihmal edilebilir düzeydedir (η^2_h = .008). Elde edilen sonuçlar, sınıf düzeyleri boyunca kimya derslerine maruz kalmanın akıl yürütmeye dayalı kavramsal anlayışta kendiliğinden ve anlamlı bir gelişime yol açmadığını göstermektedir. Çalışma, öğretmen yetiştirme programlarında kavram temelli, model odaklı ve akıl yürütmeye dayalı öğretim ve değerlendirme uygulamalarının gerekliliğine dikkat çekmektedir.

Anahtar Kelimeler: Akıl yürütme, fen bilgisi öğretmen adayı, kavramsal anlayış, kimya eğitimi, temel kimya kavramları

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Introduction

One of the primary goals of contemporary education systems is to cultivate individuals who value scientific knowledge, think critically, and are capable of generating solutions to societal problems (Ayas & Özmen, 2002; Ok, 2019; Yıldırım & Dönmez, 2008). Within this framework, science education plays a critical role in enabling individuals to understand their environment, adapt to scientific developments, and use technology effectively (Çalık, Ayaş & Ünal, 2006; Demirbaş et al., 2011; Kunduz, 2013). Among the sub-disciplines of science, chemistry stands out as a field that, despite its direct relevance to everyday life, is difficult to learn due to its abstract and multi-layered conceptual structure (Freire, Talanquer & Amaral, 2019).

The goal of chemistry education extends beyond the recognition of concepts, models, and theories; it requires learners to construct meaning through reasoning, modeling, and justification (Bodner, 1986; Bransford et al., 1999). The nature of chemistry necessitates understanding structures that cannot be directly observed—such as atoms, molecules, and reactions—thereby requiring learners to establish connections among macroscopic, microscopic, and symbolic levels of representation (Reid, 2000; Gkitzia et al., 2011; Koç, 2014). This representational complexity may lead to fragmented and surface-level learning and may result in persistent difficulties in understanding advanced topics (Nakhleh, 1992; Demircioğlu, Demircioğlu & Ayas, 2006; Yalçın-Çelik et al., 2017).

In the chemistry education literature, conceptual understanding is defined not merely as the ability to define a concept or correctly apply a formula, but as the capacity to explain and justify that concept across different contexts (Nakhleh, 1992). Nurrenbern and Pickering (1987) and Nakhleh (1992) demonstrated that students may successfully solve quantitative problems while failing to ground their solutions in conceptual reasoning. This distinction has highlighted the difference between algorithmic success and conceptual understanding. Traditional instructional approaches that prioritize procedural knowledge may therefore limit the development of conceptual reasoning (Nurrenbern & Pickering, 1987; Nakhleh, 1992).

Such difficulties are not limited to students; they are also evident among teachers and pre-service teachers. The conceptual density of chemistry and the transitions between macro- and micro-level representations require strong chemical reasoning skills (Cardellini, 2012; Kolomuç & Tekin, 2011; Tüysüz et al., 2011). Teachers' conceptual structures directly influence students' learning processes (Wheeldon, 2012). For this reason, the quality of conceptual learning within teacher education programs is considered a critical determinant of effective chemistry teaching.

Although numerous studies in the literature have examined misconceptions and learning difficulties related to fundamental chemistry concepts, relatively few have investigated pre-service science teachers' reasoning-based conceptual understanding of these concepts across grade levels in a comprehensive manner. In particular, evidence regarding how pre-service teachers' conceptual understanding evolves throughout undergraduate education remains limited, pointing to an important gap in evaluating the effectiveness of teacher education programs. In this context, there is a need for assessment tools capable of revealing conceptual understanding not merely at the correct–incorrect level, but in terms of reasoning and justification. Unlike previous studies that primarily focused on students' misconceptions or algorithmic performance, the present study examines pre-service science teachers' reasoning-based conceptual understanding using a validated instrument specifically designed to distinguish conceptual reasoning from procedural success. Furthermore, by comparing different grade levels within a teacher education program, the study provides empirical evidence regarding whether conceptual understanding develops progressively throughout undergraduate training. In this respect, the findings contribute to the evaluation of teacher education programs from a conceptual learning perspective and offer implications for restructuring chemistry instruction within such programs.

Purpose of the Study

The purpose of this study is to determine the levels of conceptual understanding of fundamental chemistry concepts among second-, third-, and fourth-year pre-service science teachers enrolled in a science teacher education undergraduate program. Conceptual understanding was measured using a reasoning-based assessment instrument, the Chemistry Concept Reasoning Test (CCRT). In addition, the study aims to examine whether these levels of conceptual understanding differ significantly across grade levels.

1. What are the levels of conceptual understanding of fundamental chemistry concepts among second-, third-, and fourth-year pre-service science teachers enrolled in a science teacher education undergraduate program?
2. Is there a statistically significant difference in the levels of conceptual understanding of fundamental chemistry concepts among pre-service science teachers at different grade levels?

Method

Research Design

This study was conducted to determine the levels of conceptual understanding of fundamental chemistry concepts, models, and theories among pre-service science teachers enrolled in a science teacher education undergraduate program, and to examine whether these levels differ across grade levels. The study employed a quantitative research approach using a descriptive survey design with a cross-sectional comparative structure that allows for comparisons among grade levels. Descriptive survey designs provide an appropriate framework for studies that aim to describe existing conditions as they occur and to examine differences among variables within a defined population (Fraenkel & Wallen, 2006). Accordingly, the pre-service teachers' existing levels of conceptual understanding of chemistry concepts were examined in their natural context, without any experimental intervention.

Participants

The participants of the study consisted of a total of 86 pre-service science teachers enrolled in a Science Teacher Education undergraduate program at a public university in Türkiye during the spring semester of the 2024–2025 academic year. Of the participants, 36 were second-year students, 22 were third-year students, and 28 were fourth-year students. Participation was voluntary, and data were collected anonymously. To ensure data confidentiality, participants were coded using identifiers such as S-2-1, S-3-1, …, S-4-12, where the middle number indicates the participant's grade level. The research process was conducted in accordance with ethical principles, ensuring the protection of participants' rights and the confidentiality of their data. The sample size reflects the accessible population within the teacher education program during the data collection period, and all eligible pre-service teachers at the relevant grade levels were invited to participate. Although the study was conducted within a single institutional context, such sampling is considered appropriate for descriptive and non-parametric analyses, which do not require large sample sizes or strict distributional assumptions (Creswell, 2012; Fraenkel & Wallen, 2006). Nevertheless, the findings should be interpreted with caution regarding their generalizability beyond similar institutional settings).

Data Collection Tools

The data collection tool used in this study was the Chemistry Concept Reasoning Test (CCRT) developed by Cloonan and Hutchinson (2011). The CCRT is designed to assess conceptual understanding and scientific reasoning related to fundamental concepts, models, and theories commonly addressed in general chemistry courses. Rather than measuring computation-based problem-solving skills, the test consists of multiple-choice items that aim to reveal students' levels of logical justification, modeling, and conceptual linkage in relation to chemical phenomena. Although the CCRT employs a multiple-choice format, it was specifically designed to assess a level of thinking comparable to that measured by open-ended, explanation-based questions (Cloonan & Hutchinson, 2011). In this respect, the instrument makes visible the distinction between algorithmic success and conceptual reasoning. The test covers core content areas in general chemistry. These include atom–molecule theory and the particulate nature of matter; atomic structure and periodic trends; chemical bonding and molecular geometry; energy and thermodynamic processes; gases and phase equilibria; chemical equilibrium and reaction kinetics; and acid–base and redox reactions. The reliability and validity of the test were established through studies conducted at Rice University. The Pearson correlation coefficients for the two versions ranged from 0.639 to 0.717, indicating that the test provides high validity and reliability in measuring conceptual knowledge. The Turkish adaptation of Version A of the original test was conducted with 368 university students who had completed a General Chemistry course. The results demonstrated a Pearson correlation coefficient of .796, indicating a strong level of reliability. In addition to this reliability evidence, the adapted version preserved the original construct structure and the conceptual intent of the items. Content and construct validity were supported through expert review conducted by faculty members specializing in chemistry education, as well as pilot administration with university students who had previously completed a General Chemistry course. These procedures ensured that the adapted version adequately represents reasoning-based conceptual understanding in the Turkish higher education context.

Scoring. In the Chemistry Concept Reasoning Test, each correct response was scored as 1 point, whereas incorrect or unanswered items were scored as 0 points. Item 6 of the test was evaluated using a partial credit scoring approach, as it included two correct options (A and B). Accordingly, selecting both correct options was awarded 1 point; selecting only one of the correct options (A or B) was awarded 0.5 points; and all other response patterns received 0 points. Based on this scoring procedure, the total possible score on the test ranged from 0 to 38.5.

Data Analysis

The data obtained in the study were analyzed using statistical software packages. First, descriptive statistics—including the mean, standard deviation, minimum, and maximum values—were calculated to describe pre-service teachers' levels of conceptual understanding of fundamental chemistry concepts. These analyses were conducted both for the total test scores and for the predefined conceptual categories. To determine the appropriate statistical tests for comparing achievement scores across grade levels, the assumption of normality was examined. The results of the normality analyses indicated that the data did not follow a normal distribution. Accordingly, the Kruskal–Wallis H test, which is suitable for comparing three independent groups, was employed to compare the achievement scores of second-, third-, and fourth-year pre-service science teachers. In cases where the Kruskal–Wallis test yielded a statistically significant result, pairwise comparisons were conducted using the Mann–Whitney U test to identify the groups between which the differences occurred. The level of statistical significance was set at .05. In addition, appropriate effect size measures were reported to facilitate the interpretation of the magnitude of the observed differences. Effect size values were interpreted following conventional guidelines for non-parametric tests, with η^2_h values below .01 indicating a negligible effect.

Findings

Following the data cleaning process, a total of 83 pre-service science teachers were included in the analyses. Of the participants, 35 were second-year students, 21 were third-year students, and 27 were fourth-year students. Examination of the overall descriptive statistics for the total scores obtained from the Chemistry Concept Reasoning Test revealed a mean score of 9.30 (SD = 2.73). The scores ranged from 4 to 16, with a median value of 9.00 (Table 1). The total possible score on the test ranged from 0 to 38.5.

Table 1. Descriptive statistics for total scores on the chemistry concept reasoning test

N	Mean	SD	Median	Min.	Max.
83	9.30	2.73	9.00	4.00	16.00

Descriptive statistics for total scores by grade level are presented in Table 2. The mean scores were 9.61 for second-year, 9.48 for third-year, and 8.74 for fourth-year pre-service teachers. Median values were 10.0 for second- and third-year students and 8.0 for fourth-year students.

Table 2. Descriptive statistics of total scores by grade level

Grade Level	N	Mean	SD	Median	Min.	Max.
Second Year	35	9.61	2.87	10.0	4.0	14.0
Third Year	21	9.48	1.90	10.0	5.5	11.5
Fourth Year	27	8.74	3.07	8.0	4.0	16.0

To examine whether total scores differed across grade levels, non-parametric comparative analyses were conducted.

Item-Based Descriptive Findings Related to Fundamental Chemistry Concepts

The items of the Chemistry Concept Reasoning Test (CCRT) were grouped into conceptual categories to examine performance across grade levels. Mean correct response rates were calculated for second-, third-, and fourth-year pre-service teachers within each conceptual domain. The results are presented in Table 3 according to grade level.

Table 3. Item-based descriptive statistics by fundamental chemistry concept

Fundamental Chemistry Concept	Related Test Items	Number of Items	2nd Year Mean (%)	3rd Year Mean (%)	4th Year Mean (%)
Atom–Molecule and Particulate Nature of Matter	S1, S2, S3, S26	4	17.9	22.6	18.5
Mole Concept and Gas Behavior	S4, S5, S24, S25	4	28.6	22.6	31.5
Atomic Structure and Periodic Trends	S6, S7, S8, S10	4	25.4	34.5	25.0
Chemical Bonding and Molecular Geometry	S11, S12, S13, S14, S15, S16, S17, S18, S29	9	25.1	19.6	18.5
Energy, Heat, and Thermodynamics	S19, S20, S21, S22, S23, S34, S35, S36	8	32.9	29.8	25.5
Chemical Equilibrium and Reaction Rate	S30, S31	2	20.0	21.4	16.7
Acid–Base and Redox	S32, S33, S38	3	28.6	31.7	22.2

Note. Percentages were calculated by dividing the number of correct responses within each conceptual category by the total number of items in that category and averaging across participants at each grade level.

An examination of Table 3 shows the mean correct response rates for each conceptual category across grade levels:

- Atom–molecule and particulate nature of matter. The mean correct response rates were 17.9% for second-year, 22.6% for third-year, and 18.5% for fourth-year pre-service teachers.
- Mole concept and gas behavior. The mean correct response rates were 28.6% for second-year, 22.6% for third-year, and 31.5% for fourth-year pre-service teachers.

- Atomic structure and periodic trends. The mean correct response rates were 25.4% for second-year, 34.5% for third-year, and 25.0% for fourth-year pre-service teachers.
- Chemical bonding and molecular geometry. Correct response rates ranged between 19.6% and 25.1% across grade levels.
- Energy, heat, and thermodynamics. The mean correct response rates were 32.9% for second-year, 29.8% for third-year, and 25.5% for fourth-year pre-service teachers.
- Chemical equilibrium and reaction rate. The mean correct response rates were 20.0% for second-year, 21.4% for third-year, and 16.7% for fourth-year pre-service teachers.
- Acid–base and redox concepts. The mean correct response rates were 28.6% for second-year, 31.7% for third-year, and 22.2% for fourth-year pre-service teachers.

Comparison of Total Scores by Grade Level

To examine whether total achievement scores differed across grade levels, the Kruskal–Wallis H test was conducted (Table 4).

Table 4. Kruskal–Wallis H test results for total scores on fundamental chemistry concepts by grade level

Grade Level		n		Mean Rank
Second Year		35		44.94
Third Year		21		43.07
Fourth Year		27		36.06
Test	**H**	**sd**	**p**	**Effect Size (η^2_h)**
Kruskal–Wallis H	2.632	2	.268	.008

The Kruskal–Wallis H test showed no statistically significant difference in total scores across grade levels ($H(2) = 2.632$, $p = .268$). The mean ranks were 44.94 for second-year, 43.07 for third-year, and 36.06 for fourth-year pre-service teachers. The calculated effect size was $\eta^2_h = .008$.

Discussion

This study examined the reasoning-based conceptual understanding of fundamental chemistry concepts among pre-service science teachers using the Chemistry Concept Reasoning Test (CCRT). The findings revealed low overall achievement and no statistically significant differences across grade levels. These results are consistent with prior research indicating that traditional chemistry instruction may enhance procedural performance without necessarily promoting conceptual reasoning (Cloonan & Hutchinson, 2011).

Conceptual vs. Algorithmic Understanding

Conceptual understanding in chemistry extends beyond recalling definitions or applying formulas; it involves explaining concepts across contexts and justifying reasoning (Nakhleh, 1992). Previous research has shown that students may successfully solve quantitative problems while failing to ground their solutions in conceptual reasoning (Nurrenbern & Pickering, 1987; Nakhleh, 1992).

The low performance observed in domains such as atom–molecule relationships, particulate nature of matter, the mole concept, and chemical bonding suggests challenges in constructing integrated conceptual frameworks. These findings align with studies emphasizing that conceptual development requires representational diversity, explicit reasoning, and model-based explanation rather than reliance on procedural knowledge alone (Nakhleh, 1992; Cloonan & Hutchinson, 2011).

In comparison with previous research, the present findings demonstrate a pattern similar to studies reporting persistent conceptual difficulties among university-level learners (Nakhleh, 1992; Nurrenbern & Pickering, 1987). However, unlike some studies that report gradual conceptual improvement across years of study, the absence of statistically significant differences across grade levels in this study suggests a lack of progressive conceptual restructuring within the examined teacher education context. This distinction highlights the importance of examining not only whether conceptual difficulties exist, but also whether instructional structures effectively support long-term conceptual development.

Lack of Conceptual Progress Across Grade Levels

A notable finding of this study is the absence of significant improvement in conceptual understanding as grade level increases. Although students advance through the teacher education program, their reasoning-based performance does not demonstrate progressive development.

Within the examined curriculum, fundamental chemistry concepts are primarily addressed during the first two years of undergraduate education, while upper-grade coursework increasingly emphasizes pedagogical knowledge. Consequently, opportunities for revisiting and restructuring disciplinary conceptual understanding appear limited.

Consistent with Nieswandt (2006), durable conceptual understanding requires repeated engagement with concepts across contexts and opportunities for active reconstruction. The lack of significant differences across grade levels may therefore reflect limitations in curricular continuity.

Instructional Approaches and Textbook Structure

Difficulties observed in particulate nature of matter, bonding, and molecular geometry may also be associated with instructional approaches and textbook structures. Research based on Bloom's taxonomy and the work of Niaz (2005) indicates that chemistry textbooks often adopt a result-oriented and algorithmic presentation style. Such approaches may restrict learners' opportunities to engage in explanatory reasoning.

Similarly, Çetin-Dindar and Geban (2016) and Andayani et al. (2018) report that instructional materials frequently fail to sufficiently activate higher-order cognitive processes, potentially limiting conceptual depth.

Conclusion

This study demonstrates that pre-service science teachers' reasoning-based conceptual understanding of fundamental chemistry concepts remains limited and does not significantly improve across grade levels. The findings suggest that exposure to disciplinary content alone is insufficient to promote conceptual restructuring unless instructional practices explicitly target reasoning, representation, and model-based explanation.

These results highlight the importance of integrating sustained conceptual development opportunities within teacher education programs to support the preparation of future teachers capable of fostering deep conceptual understanding in their own classrooms.

Implications for Assessment and Teacher Education

The findings suggest that teacher education programs should move beyond early exposure to fundamental chemistry concepts and ensure their systematic revisiting and restructuring across upper-grade coursework. In particular, reasoning-based assessment tools such as the CCRT may be integrated into third- and fourth-year disciplinary or methods courses to monitor and support ongoing conceptual development.

Rather than confining fundamental chemistry instruction to the first years of undergraduate study, programs may incorporate structured opportunities for conceptual reconstruction through model-based discussions, diagnostic assessments, and reflective reasoning tasks in upper-grade courses. Embedding reasoning-focused assessments into program-level evaluation practices may help identify persistent conceptual gaps and support sustained conceptual growth.

Furthermore, curriculum designers may consider aligning disciplinary content courses and pedagogy courses to explicitly connect conceptual understanding with instructional practice. Such alignment may strengthen pre-service teachers' ability to both understand and teach fundamental chemistry concepts at a deep level.

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Genişletilmiş Özet

Giriş

Günümüz eğitim sistemlerinin temel amaçlarından biri; bilimsel bilgiye değer veren, eleştirel düşünebilen ve toplumsal sorunlara çözüm üretebilen bireyler yetiştirmektir. Bu bağlamda fen eğitimi, bireylerin çevrelerini anlamaları, teknolojiyi etkin şekilde kullanmaları ve bilimsel gelişmelere uyum sağlamaları açısından önemli bir rol üstlenmektedir. Fen bilimlerinin alt disiplinleri içinde kimya, soyut ve çok katmanlı yapısı nedeniyle öğrenilmesi güç bir alan olarak öne çıkmaktadır.

Kimya eğitiminin amacı yalnızca kavram ve teori öğretimi değildir; öğrencilerin modelleme, akıl yürütme ve gerekçelendirme yoluyla bilgiyi yapılandırması beklenmektedir. Buna karşın araştırmalar, öğrencilerin makro, mikro ve sembolik düzeylerdeki temsilleri eşzamanlı olarak anlamakta zorlandıklarını ve bu durumun kavramsal öğrenmeye engel oluşturduğunu göstermektedir. Bu güçlükler yalnızca öğrencilerde değil, öğretmen ve öğretmen adaylarında da ortaya çıkmakta; kavramsal yoğunluk ve soyut temsillerin gerektirdiği bilişsel süreçler öğretimi zorlaştırmaktadır.

Bu nedenle öğretmen adaylarının kavramsal anlama düzeyleri, öğretim programlarının etkililiği açısından kritik öneme sahiptir. Ancak mevcut literatürde, öğretmen adaylarının temel kimya kavramlarını sınıf düzeyleri boyunca nasıl geliştirdiklerine ilişkin kapsamlı çalışmaların sınırlı olduğu vurgulanmaktadır. Özellikle doğru–yanlış temelli ölçümlerin ötesinde, gerekçelendirmeye dayalı kavramsal anlama düzeylerini ortaya koyan araçlara ihtiyaç duyulmaktadır.

Yöntem

Bu çalışma, fen bilgisi öğretmenliği lisans programında öğrenim gören öğretmen adaylarının temel kimya kavramlarına ilişkin kavramsal anlama düzeylerini belirlemek ve sınıf seviyelerine göre farklılaşıp farklılaşmadığını incelemek amacıyla yürütülmüştür. Araştırmada, sınıf düzeyleri arasında karşılaştırma yapılmasına imkân veren nicel, betimsel tarama türünde kesitsel karşılaştırmalı bir desen kullanılmıştır (Fraenkel ve Wallen, 2006). Veri toplama sürecinde herhangi bir deneysel müdahaleye yer verilmemiş; katılımcıların mevcut durumu doğal bağlamında incelenmiştir.

Çalışma Grubu

Çalışmaya 2024–2025 bahar döneminde Türkiye'deki bir devlet üniversitesinin fen bilgisi öğretmenliği programında öğrenim gören toplam 86 öğretmen adayı katılmıştır. Katılımcıların 36'sı 2. sınıf, 22'si 3. sınıf ve 28'i 4. sınıf öğrencisidir. Katılım gönüllüdür, veriler anonim olarak toplanmıştır ve katılımcılar S-2, S-3 ve S-4 şeklinde kodlanarak gizlilik sağlanmıştır. Araştırma etik ilkeler doğrultusunda gerçekleştirilmiştir.

Veri Toplama Aracı

Veriler, Cloonan ve Hutchinson (2011) tarafından geliştirilen Kimya Kavram Akıl Yürütme Testi ile toplanmıştır. Test, işlem becerilerinden ziyade kavramların gerekçelendirilerek modellenmesi ve bilimsel akıl yürütme süreçlerini ölçen çoktan seçmeli maddelerden oluşmaktadır. İçeriği atom–molekül yapısı, atom modeli ve periyodik özellikler, bağlanma ve moleküler yapı, termodinamik, gazlar, denge ve kinetik ile asit-baz ve redoks konularını kapsamaktadır. Testin güvenilirliği orijinal uygulamalarda 0.639–0.717, Türkçe uyarlamada 0.796 Pearson korelasyon katsayısı ile doğrulanmıştır. Uyarlama sürecinde uzman görüşleri ve pilot uygulamalarla kapsam ve yapı geçerliliği sağlanmıştır.

Puanlama. Doğru maddeler 1 puan, yanlış ve boş yanıtlar 0 puan olarak değerlendirilmiştir. Altıncı maddede iki doğru seçenek bulunduğundan, tam doğru yanıt 1 puan, tek doğru seçenek 0.5 puan olarak puanlanmıştır. Toplam test puanı 0–38.5 arasında değişmektedir.

Veri Analizi

Elde edilen veriler istatistik paket programlarıyla analiz edilmiştir. Öncelikle betimsel istatistikler hesaplanmış; normal dağılım şartları sağlanmadığı için Kruskal–Wallis H testi ile sınıf düzeyleri arasında fark olup olmadığı incelenmiştir. Anlamlı bulunması durumunda farklılığın kaynağını belirlemek üzere Mann–Whitney U testi yapılmıştır. Anlamlılık düzeyi .05 olarak belirlenmiş;

etki büyüklüğü hesaplanmış ve non-parametrik eşikler doğrultusunda yorumlanmıştır.

Sonuçlar

Veri temizliği sonrasında toplam 83 fen bilgisi öğretmen adayı analize dâhil edilmiştir (35 ikinci sınıf, 21 üçüncü sınıf, 27 dördüncü sınıf). Kimya Kavram Akıl Yürütme Testinden elde edilen toplam puanların betimsel analizine göre öğretmen adaylarının ortalama puanı 9.30 (SS = 2.73) olup puanlar 4 ile 16 arasında değişmiştir. Testin maksimum puanının 38.5 olduğu düşünüldüğünde, öğretmen adaylarının genel başarı düzeylerinin sınırlı olduğu belirlenmiştir.

Sınıf düzeyine göre ortalama puanlar ikinci sınıfta 9.61, üçüncü sınıfta 9.48 ve dördüncü sınıfta 8.74 olarak hesaplanmış; medyan değerler de benzer bir dağılım göstermiştir. Bu betimsel bulgular, sınıf düzeyleri arasında belirgin bir farklılık olmadığını göstermektedir.

Test maddeleri kimya kavram alanlarına göre incelendiğinde, tüm sınıf düzeylerinde başarı oranlarının düşük olduğu görülmüştür. Hiçbir kavramsal alanda ortalama doğru yanıtlama oranı %35'i aşmamıştır. Özellikle;

- Atom–molekül ve madde tanecikliliği,
- Kimyasal bağlanma ve moleküler geometri,
- Denge ve hız,
- Asit–baz ve redoks alanlarında başarı oranları belirgin biçimde düşüktür. Enerji ve termodinamik konuları görece daha yüksek olmakla birlikte başarı düzeyleri yine orta düzeye yaklaşmamaktadır.

Sınıf düzeyleri arasındaki farklılıkların anlamlılığını incelemek amacıyla uygulanan Kruskal–Wallis H testi, toplam puanlarda istatistiksel olarak anlamlı bir fark bulunmadığını göstermiştir ($H(2)=2.632$, $p=.268$). Etki büyüklüğünün çok küçük ($\eta^2_h=.008$) olması, sınıf düzeyinin kavramsal anlama üzerinde anlamlı bir belirleyici olmadığını göstermektedir.

Tartışma

Bu çalışmada fen bilgisi öğretmen adaylarının temel kimya kavramlarına ilişkin kavramsal anlamaları Cloonan ve Hutchinson (2011) tarafından geliştirilen Kimya Kavram Akıl Yürütme Testi ile incelenmiştir. Hesaplamaya dayalı başarı yerine muhakeme, modelleme ve açıklama gerektiren düşünme süreçlerini ortaya koyan test bulguları, öğretmen adaylarının kavramsal düzeylerinin genel olarak düşük olduğunu ve sınıf düzeyine bağlı anlamlı bir artış göstermediğini ortaya koymuştur. Bu sonuçlar, geleneksel kimya öğretiminin algoritmik performansı artırmakla birlikte kavramsal akıl yürütmeyi yeterince desteklemediğini gösteren literatürle uyumludur (Cloonan ve Hutchinson, 2011).

Kimya eğitiminde kavramsal anlama, yalnızca tanım ezberleme ya da formül uygulama değil; farklı bağlamlarda açıklama yapma ve neden–sonuç ilişkileri kurma yeterliği olarak tanımlanmaktadır (Nakhleh, 1992). Öğrencilerin sayısal problemleri çözebilmesine rağmen kavramsal temellendirme yapamamalarını gösteren çalışmalar (Nurrenbern ve Pickering, 1987; Nakhleh, 1992) ile paralel olarak, bu çalışmada atom–molekül, mol kavramı ve kimyasal bağlanma gibi temel alanlarda düşük başarı, öğretmen adaylarının kavramsal şemalarının bütünleşmediğini göstermektedir.

Bulgular aynı zamanda sınıf düzeyleri arasında anlamlı fark olmamasının, program yapısındaki belirgin bir özellikten kaynaklanabileceğini göstermektedir. Temel kimya konularının çoğu programın ilk iki yılında ele alınmakta, üst sınıflarda ise pedagoji ağırlıklı dersler öne çıkmaktadır. Kavramların yeniden yapılandırılması ve farklı bağlamlarda ele alınması için yeterli fırsat sunulmaması, Nieswandt (2006)'ın vurguladığı "kavramsal öğrenmenin süreklilik gerektirdiği" görüşü ile örtüşmektedir.

Literatürde kimya ders kitaplarının çoğunlukla sonuç odaklı ve algoritmik bir anlatımla sunulduğu ve öğrencilerin kavramsal sorgulama fırsatlarını sınırladığı belirtilmektedir (Niaz, 2005; Çetin-Dindar ve Geban, 2016; Andayani, Hadisaputra ve Hasnawati, 2018). Benzer şekilde Heyworth (1999) ve Rempel vd. (2021), kavramsal akıl yürütmeyi değerlendirmeyen ölçme araçlarının öğrencilerin öğrenme eksikliklerini fark etmesini engellediğini vurgulamaktadır. Bu açıdan testin öğrenenlerin kavramsal boşluklarını görünür kılması önemli bir kazanımdır.

Sonuç olarak çalışma, öğretmen adaylarının temel kimya kavramlarına ilişkin kavramsal anlamalarının sınırlı düzeyde kaldığını ve sınıf düzeyi arttıkça kendiliğinden gelişmediğini göstermektedir. Bulgular, öğretmen eğitiminde kavram temelli, model odaklı öğretim yaklaşımlarının ve kavramsal akıl yürütmeyi ölçen değerlendirme uygulamalarının gerekliliğine dikkat çekmektedir (Cloonan ve Hutchinson, 2011; Heyworth, 1999; Nieswandt, 2006).

Öneriler

Gelecekte yapılacak araştırmaların, farklı üniversite ve daha geniş örneklemler üzerinde yürütülmesi önerilmektedir. Fen bilgisi dışındaki öğretmen yetiştirme programlarının da incelenmesi, alanlar arası karşılaştırma fırsatı sağlayacaktır. Bunun yanı sıra, açık uçlu sorular, görüşmeler ve sesli düşünme protokolleri gibi nitel yöntemlerin kullanılması, öğretmen adaylarının kavramsal eksikliklerinin nedenlerini daha derinlemesine ortaya koyabilir. Boylamsal çalışmaların yapılması, kavramsal gelişimin zaman içinde nasıl ilerlediğini ve hangi öğretim deneyimlerinin bu süreci desteklediğini göstermesi açısından önem taşımaktadır. Ayrıca, kavram temelli ve modele dayalı öğretim müdahalelerini değerlendiren deneysel çalışmalar ile ders kitapları, öğretim materyalleri ve ölçme uygulamalarının kavramsal öğrenmeyi destekleme düzeyini inceleyen araştırmalar, öğretmen yetiştirme programlarının gelişimine önemli katkılar sağlayacaktır.

Araştırmanın Etik Taahhüt Metni

Yapılan bu çalışmada bilimsel, etik ve alıntı kurallarına uyulduğu; toplanan veriler üzerinde herhangi bir tahrifatın yapılmadığı, karşılaşılacak tüm etik ihlallerde “Sivas Cumhuriyet Üniversitesi Eğitim Bilimleri Enstitüsü Dergisi ve Editörünün” hiçbir sorumluluğunun olmadığı, tüm sorumluluğun Sorumlu Yazara ait olduğu ve bu çalışmanın herhangi başka bir akademik yayın ortamına değerlendirme için gönderilmemiş olduğu sorumlu yazarlar tarafından taahhüt edilmiştir.

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