

VISUALIZING SOLUBILITY: A STUDY ON GIFTED STUDENTS' GRAPH INTERPRETATION ABILITIES

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Abstract

This study aimed to determine gifted students' levels of skill in reading and interpreting solubility-related graphs, as well as performing interpolation and extrapolation using graphical data. A case study design, one of the descriptive research methods, was employed. As part of this design, a two-part test was used as the data collection tool. After piloting the test, it was administered to 64 high school gifted students who had completed a course on "Solubility and Factors Affecting Solubility" and who voluntarily participated in the study. The data collected were analyzed using basic statistical methods. The results indicated that gifted students performed better in reading solubility graphs than in interpreting them. However, their extrapolation skills were found to be below the expected level. Moreover, while there was a relationship between the students' conceptual understanding and their graphical skills, deficiencies in graph-related competencies were more pronounced. The findings of this study are expected to serve as a guide for future efforts aimed at improving graphing skills—one of the key components of scientific process skills.

Keywords: gifted education, scientific process skills, graph literacy, graph reading, graph interpretation

INTRODUCTION

Science education requires not only the learning of scientific content but also the development of essential skills known as scientific process skills. The relative importance of acquiring these two components—content knowledge and process skills—has been a frequent topic of debate in the literature (e.g., Dolapcioglu & Subasi, 2022). However, such a debate can be seen as somewhat redundant, as numerous studies have emphasized that the two are closely interconnected and mutually supportive—each facilitating the development of the other (e.g., Dolapcioglu & Subasi, 2022; Gizaw & Sota, 2023). Therefore, helping students acquire both components is generally regarded as essential. This emphasis is also clearly reflected in national and international science curricula (MoNE, 2013, 2018, 2024; Özalp, 2023). A wide body of research on scientific process skills has been conducted for decades, offering various perspectives. These perspectives include studies examining the relationship between scientific process skills and (a) academic achievement (e.g., Barut & Yüce, 2025), (b) attitudes toward science (e.g., Perdana et al., 2022), and (c) scientific creativity (e.g., Yildiz & Yildiz, 2021). Across all of these studies, significant positive correlations have been found between scientific process skills and the aforementioned variables. Additionally, research has shown that scientific process skills contribute to the development of higher-order thinking skills, such as problem-solving, critical thinking, and decision-making (e.g., Ceylan, 2024). In short, these findings strongly underscore the importance of equipping students with scientific process skills from multiple perspectives. An individual with well-developed scientific process skills can take an active role in learning, acquire scientific knowledge more effectively, and construct meaningful and lasting understanding while avoiding misconceptions (Temiz & Tan, 2003; Şen & Nakiboğlu, 2012). From this perspective, the effectiveness of science instruction is closely linked to how well these skills are cultivated. In addition to being the skills used by scientists in their work, scientific process skills also form the foundation of scientific thinking and research (Temiz & Tan, 2003). Among these skills—classified in various ways in the literature—are graph-related skills, including reading, interpreting, and drawing graphs.

Graphs are one of the most frequently encountered visual representations in both education and everyday life. By making abstract and complex information more accessible, graphs play an increasingly important role across nearly all academic disciplines, particularly in mathematics and science (Bayazıt, 2011). As visual materials, graphs are among the most widely used tools for organizing instructional environments and enriching learning processes (Belér, 2009; Bengtsson & Ottosson, 2006; Okur & Güngör Seyhan, 2025). While graphing skills are widely recognized as important for both science education and real-life applications, numerous studies indicate that many students struggle to acquire them (e.g., Bayazıt, 2011; Belér, 2009; Bowen & Roth, 2005; Dori & Sason, 2008; Okur & Güngör Seyhan, 2025; Potgiether et al., 2008). Students' difficulties are not limited to graph reading, drawing, or interpretation. Poor performance on national and standardized assessments in Turkey—especially in questions involving graphs—also points to widespread challenges in graph-related tasks (e.g., Coştu, 2023; Coştu, 2007, 2010; Kurnaz, 2013). Due to both the importance of acquiring graphing skills and the prevalence of difficulties in doing so, this area has attracted significant research attention. One key step in improving graphing skills—especially for gifted students—is identifying their current strengths and difficulties. From this standpoint, evaluating the graph-related abilities of gifted students has emerged as an important research problem.

Graph Reading, Drawing, and Interpretation Skills

Graph reading and interpretation are not innate abilities but learned skills that require both conceptual understanding and procedural practice (Dreyfus & Eisenberg, 1990; Okur & Güngör Seyhan, 2025; Wu, 2004). Graphic literacy involves interpreting, creating, and evaluating visual representations such as graphs, maps, and diagrams, and includes identifying errors and understanding graphical conventions like scaling and labeling (Yeniçeri & Bulut, 2023; Berg & Boote, 2017). These skills are essential for scientific literacy and are emphasized across K–12 and higher education curricula (Glazer, 2011; Kaleli Yilmaz & Yurtyapan, 2021; Roth et al., 1999). Research shows that students at all levels—including university—struggle with graph interpretation, often making systematic errors or treating graphs as pictorial rather than symbolic representations (Beichner, 1994; Kaleli Yilmaz & Yurtyapan, 2021; Okur & Güngör Seyhan, 2025). Difficulties are particularly evident with more complex graphs, such as those representing motion or distributions (Ben-Zvi, 2004). Even preservice teachers require more training in these skills (Bowen & Roth, 2005). Technology-enhanced learning environments, such as microcomputer-based laboratories (MBL), offer real-time graphing and immediate feedback, helping students link physical phenomena with graphical data (e.g., Mokros & Tinker, 1987). While digital tools simplify graph creation, targeted instruction remains essential to develop interpretation skills and overcome common misconceptions.

Graphical Literacy in Türkiye

Recent curricular reforms in Türkiye, particularly through The Century of Türkiye Education Model, emphasize the integration of visual data literacy—such as graphs, tables, and diagrams—beginning at the preschool level (MoNE, 2024). Graph-related skills are progressively developed across grade levels and subjects, including science, mathematics, social studies, and Turkish language. Students are expected not only to read graphs but also to interpret data, conduct simple analyses, and apply mathematical modeling in real-world contexts, such as deriving relationships in electricity or analyzing consumption trends. In addition to the general education system, gifted students in Türkiye receive specialized instruction through the Science and Art Centers (BİLSEM), which operate under the MoNE. BİLSEM institutions provide individualized and project-based learning opportunities designed to nurture gifted students' scientific reasoning, creativity, and problem-solving skills (e.g., Paçacı, 2024). The curriculum in BİLSEM emphasizes inquiry-based and research-oriented approaches, encouraging students to engage in experimental work, data analysis, and scientific communication (e.g., Ayverdi et al., 2025). In science education modules, graph reading, drawing, and interpretation are integral components of both laboratory and project activities, as students are expected to visualize and analyze data collected from experiments. The present study was conducted in one of these BİLSEM centers, where students regularly participate in such activities aimed at developing higher-order thinking and data literacy skills. This shift reflects broader educational goals

aligned with 21st-century competencies, where individuals are expected to transfer and apply data across disciplines. Graph literacy enables students to evaluate data critically, recognize misleading representations, and make informed decisions (OECD, 2019a, 2019b). Research further supports that inquiry-based, open-ended approaches enhance students' graph interpretation skills more effectively than traditional methods (Gültepe, 2016; Karatay et al., 2024). Therefore, promoting graph literacy from early education is essential for developing scientifically literate and analytically capable individuals.

Literature Review

A substantial number of studies—both national and international—have examined students' skills in graph drawing, reading, and interpretation. The volume of research in this area underscores the importance of understanding students' knowledge and skill levels related to graphs in detail. Existing literature shows that deficiencies and misconceptions in graph-related skills are frequently explored across different educational stages. These studies span nearly every level of education, from early primary years to the university level. However, while relatively few studies focus on elementary school students (e.g., Parmar & Signer, 2005; Selamet, 2014), research becomes more common at the middle school (e.g., Memnun, 2013; Yayla & Özsevgeç, 2015) and high school levels (e.g., McKenzie & Padilla, 1986), and is most prevalent at the university level (e.g., Beichner, 1994; Bowen & Roth, 2005; Kılıç et al., 2012). Regardless of educational level, these studies consistently reveal that students face a wide range of challenges when it comes to graph drawing, reading, and interpretation. In fact, it has been noted that students tend to perform more poorly on graph-based questions compared to conceptual or procedural questions in learning environments (Coştu, 2023; Coştu, 2007). Another common finding from studies such as those by Tairab & Khalaf Al-Naqbi (2004) and Taşar et al. (2002) is that students struggle more with drawing graphs than with reading or interpreting them. While many studies focus on identifying students' difficulties with graphing, some research has explored different dimensions of graph-related skills. For example, Berg and Phillips (1994) investigated the relationship between logical thinking and graphing abilities and found a correlation between the two. Other studies (e.g., Memnun, 2013; Parmar & Signer, 2005) examined the link between students' mathematical and graphing skills, identifying a positive relationship. In addition, a study by Gültekin and Nakiboğlu (2016) evaluated how chemistry curricula introduced at different times addressed graphing skills. Their findings revealed that curriculum content provided insufficient emphasis on graphing outcomes, a problem also reflected in textbooks aligned with those curricula. Recent findings from Okur & Güngör Seyhan (2025) further demonstrate that even at the university level, prospective science teachers display substantial deficiencies in graphing abilities, particularly when required to interpret or draw graphs under experimental conditions. The research emphasized that conventional laboratory environments do not adequately support the development of these skills, particularly when digital feedback and real-time data visualization are absent. There are also studies aimed at addressing students' graph-related difficulties. Most of these have used computer-assisted applications (e.g., Çelik & Pektaş, 2017; Dori & Sason, 2008; Uyan & Önen, 2013) and have shown that such interventions effectively improved students' graphing skills. Beyond digital tools, alternative approaches have also been implemented. For instance, technologies such as CBR (Calculator-Based Ranger) and MBL (Microcomputer-Based Laboratory) have been used (Svec, 1995; Kwon, 2002), as well as non-technological methods like cooperative learning strategies (e.g., Taşdemir et al., 2005), all yielding positive outcomes in terms of enhancing graphing skills. Furthermore, some studies (e.g., Köse, 2011) suggest that courses integrating statistics and graph usage also contribute to the development of graph-related competencies. Within the framework of mobile learning, real-time graph generation using MBL devices like the NOVA5000 has been shown to significantly enhance students' ability to interpret dynamic relationships (Mokros & Tinker, 1987; Barclay, 1985). In the study by Okur & Güngör Seyhan (2025), the intervention group using sensor-integrated mobile devices demonstrated significantly higher performance in both graph drawing and interpretation than the control group using traditional tools. This aligns with arguments by Glazer (2011), who highlight that immediate, real-time feedback in graphical tasks can foster deeper understanding and enable hypothesis testing through exploratory 'what if' scenarios.

The studies discussed above have addressed a variety of issues related to graph drawing, reading, and interpretation. As such, the existing literature is quite diverse. However, there remain certain gaps that have not yet been sufficiently explored. One of these gaps is the skill of using graphs to perform interpolation (estimating values between known data points) and extrapolation (predicting values beyond the given data range). Although one study conducted in Turkey (Coştu et al., 2017) attempted to measure interpolation and extrapolation skills, the participants were preservice teachers rather than gifted students. A second gap in the literature concerns whether students' deficiencies in graphing stem from a lack of content knowledge. While Beler (2009) briefly touched on this issue, interpolation and extrapolation skills were not addressed at all. These two gaps—(1) limited focus on interpolation/extrapolation and (2) the unclear role of content knowledge in graphing deficiencies—have not been adequately addressed in the studies reviewed here. In this context, the work by Okur & Güngör Seyhan (2025) stands out, as it not only confirms students' difficulties in interpolation and extrapolation but also highlights the critical importance of conceptual understanding in overcoming graph-related challenges. The integration of the 5E learning model with mobile technology offered a dual benefit: enhancing students' cognitive engagement and providing them with the technical tools to visualize and model scientific data meaningfully. The present study takes these two underexplored issues into account. By addressing these gaps, it aims to contribute to the literature by investigating areas that have been largely overlooked in previous research.

Giftedness and Graph Interpretation

Gifted students are often perceived as individuals who naturally excel in abstract reasoning, problem-solving, and higher-order thinking (e.g., Yıldız, 2022). However, research increasingly shows that high cognitive potential does not guarantee procedural proficiency—particularly in areas like graph reading and interpretation (e.g., Coştu, 2023). Despite their advanced conceptual understanding, gifted learners may still struggle with tasks requiring the accurate translation of numerical data into visual representations, as well as with skills such as interpolation and extrapolation, which demand not only mathematical reasoning but also an understanding of the structure and purpose of graphs. Although literature on graph interpretation is extensive, most studies focus on general education students, and few address how gifted students engage with graphical information. This is a significant gap, especially considering that visual data representation is a cornerstone of scientific process skills. In this context, identifying and understanding the specific graphing challenges faced by gifted learners is a critical step toward designing effective, differentiated instructional strategies. Doing so not only enhances their graph literacy but also supports the broader development of their scientific reasoning and inquiry skills.

Purpose of the Study

The primary aim of this study is to determine the levels of graph reading and interpretation among gifted students related to the topic of solubility. In line with this main objective, the study also seeks to address the following three sub-goals:

- (1) To identify gifted students' levels of skill in reading and interpreting graphs related to solubility,
- (2) To determine their ability to perform interpolation and extrapolation using data presented in solubility graphs,
- (3) To explore the relationship between gifted students' conceptual knowledge and their graphing skills.

METHOD

A case study design, one of the descriptive research methods, was employed in this study, which enables in-depth exploration within a small sample. This approach involves examining a specific case in detail, collecting data systematically, and investigating possible relationships between variables. As it allows for a thorough analysis of a given phenomenon within a limited timeframe, it is considered an appropriate method for individually conducted studies (Çepni, 2007; Karasar, 2008). The sample

of the study consisted of 64 high school gifted students who had received instruction on the topic of “Solubility and Factors Affecting Solubility,” and voluntarily agreed to participate in the study. As part of the course content, the students had already encountered graphs and worked with concepts related to solubility and its influencing factors—directly aligned with the focus of this research.

Data Collection Tool

To assess gifted students’ graph reading and interpretation skills related to solubility, a two-part test developed by the researcher was used as the data collection instrument. During the development process, relevant textbooks, national examination items, and data collection tools used in prior national and international studies on graphing were reviewed. The first part of the test was designed to identify difficulties students face in reading graphs, interpreting data, and performing interpolation (estimating values between given data points) and extrapolation (predicting values beyond the given data range). In this section, a solubility-temperature graph was provided, representing the solubility of nine different compounds in water over a temperature range of 0–100°C (Appendix 1). Based on this graph, students responded to 25 open-ended questions. Questions 1 to 10 assessed graph reading skills, questions 11 to 20 focused on graph interpretation, and questions 21 to 25 aimed to evaluate students’ abilities in interpolation and extrapolation. Each item and its subparts were analyzed under three categories: “correct,” “incorrect,” and “blank.” Incorrect responses were further examined qualitatively to identify the nature of students’ misconceptions and difficulties. The second part of the test consisted of 12 conceptual statements related to solubility (Appendix 1). This section was designed to determine whether incorrect responses in Part 1 were due to misconceptions about solubility or stemmed from procedural difficulties with graph reading and interpretation, despite adequate conceptual understanding. To ensure alignment between test content and purpose, the statements in Part 2 were constructed to reflect key knowledge required to answer the graph-based questions correctly. Students were asked to evaluate each statement as either true or false.

During analysis, student responses from the open-ended items in Part 1 were compared with their evaluations of the relevant conceptual statements in Part 2. Using this comparison, a question–statement alignment was performed. Based on this alignment, eight categories (as shown in Table 1) were established. The frequency and percentage distributions of students’ responses across these categories were then analyzed to better understand the relationship between their conceptual knowledge and graphing performance. To ensure the validity of the data collection tool, both parts of the test were reviewed by three experts in science education and two chemistry educators for content relevance, clarity, and representativeness of the learning objectives. Expert feedback was used to revise the wording of several items and to confirm that the test appropriately measured both conceptual and procedural dimensions of graphing. This process ensured strong content validity. Additionally, a pilot implementation was conducted with 12 gifted students who were not part of the main study to evaluate the comprehensibility, difficulty level, and structural alignment of the items. Feedback obtained from the pilot study led to minor adjustments in the test layout and question phrasing. In terms of reliability, inter-rater reliability was established for the scoring of open-ended responses in Part 1. Two independent raters coded a random sample of 25% of the responses using the predefined categories (“correct,” “incorrect,” “blank”). Cohen’s Kappa Coefficient was calculated as 0.88, indicating a high level of agreement between raters. To maintain scoring consistency, the researcher reviewed all coding results to resolve any discrepancies. Furthermore, internal consistency reliability for Part 2 (the true–false section) was determined using the Kuder–Richardson Formula 20 (KR-20), yielding a reliability coefficient of 0.85, which is considered acceptable for educational assessments. These procedures demonstrate that both the test instrument and the analytical process were valid and reliable for the purposes of this study.

Table 1. Categories used in the analysis of the second part of the test

Statement	Question Item Matching Statement	Categories
True	Correct	True Statement - Correct Answer (TC)
False	Correct	False Statement - Correct Answer (FC)
Blank	Correct	Blank - Correct Answer (BC)
True	Incorrect	True Statement - Incorrect Answer (TI)
True	Blank	True Statement - Blank (TB)
False	Incorrect	False Statement - Incorrect Answer (FI)
Blank	Incorrect	Blank - Incorrect Answer (BI)
False	Blank	False Statement - Blank (FB)

The TI and TB categories presented in the table represent incorrect responses given by the gifted students, which stemmed from deficiencies in their graph reading and interpretation skills, despite their accurate conceptual understanding of the topic assessed in the test item. Consequently, the frequencies and percentages associated with these two categories were examined and interpreted in greater detail.

RESULTS

The findings and interpretations from the first section of the test are presented separately for each category. The descriptive results about students' graph reading skills, as assessed through Questions 1 to 10, are summarized in Table 2. These results provide an overview of the frequency and percentage distributions of students' responses across the identified categories.

In Question 1, the gifted students were asked to identify the graph representing the substance least affected by temperature changes, based on the relationship between temperature and solubility variables among the graphs given. This question was answered correctly by 75% of the participants and incorrectly by 25% (Table 2). The most common incorrect responses were KI (7 participants) and $\text{Ce}_2(\text{SO}_4)_3$ (7 participants). The selection of KI likely stemmed from participants' tendency to perceive the graph as a visual image rather than a data representation—believing that the curve occupying the smallest area on the graph paper corresponded to the substance least affected by temperature. In contrast, the choice of $\text{Ce}_2(\text{SO}_4)_3$ appears to reflect the misconception that it was least affected by temperature because its solubility decreased the least as temperature increased. In Question 2, participants were asked to determine the graph showing the substance with the greatest increase in solubility as the temperature rose. This item was answered correctly by 92% of the gifted students, and incorrectly by 8%. In Question 3, participants were asked to identify the substance whose solubility showed the greatest decrease with increasing temperature. This question was answered correctly by 98% of the participants, and incorrectly by 1%. In Question 4, the gifted students were asked to find the graph corresponding to the substance with the highest solubility value at a given temperature. The majority of participants (72%) answered this question incorrectly, while only 26% provided the correct response. Among the incorrect answers, the most frequent response was NaNO_3 (37 participants). This result may be attributed to the misconception that the plotted curve represents only values within the data range provided on the graph, rather than extrapolating beyond it. In Question 5, participants were asked to identify the graph of the substance with the lowest solubility value at a specified temperature. This question was answered correctly by 89% of the gifted students, while 9% responded incorrectly. In Question 6, the gifted students were required to determine the temperature value corresponding to a given solubility value of a substance. This question was answered correctly by 84% of the participants, incorrectly by 14%, and left unanswered by 2%. An examination of the incorrect responses revealed a wide range of temperature values—from 28°C to 40°C—with 40°C (5 participants) being the most frequent incorrect answer. These results suggest that some gifted students experienced difficulties matching data pairs accurately when reading graphs. In Question 7, participants were asked to use the information on the graph to determine the missing temperature value for the data pair (x, 130) from the KNO_3 solubility curve and to calculate the increase by finding the difference between the initial and final temperature values. This question was answered correctly by 56% of the gifted students, incorrectly by 19%, and left unanswered by 25%. Since this item required a two-step process—first locating the correct data pair and then calculating

the temperature difference—it appears that some participants struggled to identify the appropriate data point. In contrast, others had difficulty performing the calculation of the temperature difference.

Table 2. Frequencies and percentages of responses to graph reading questions

Question	True Response	True		Blank		Students responses	False	
		f	%	f	%		f	%
1	NaCl	48	75	-	-	Ce ₂ (SO ₄) ₃	7	25
						KI	7	
						KCl	1	
						KClO ₃	1	
2	KNO ₃	59	92	-	-	KClO ₃	1	8
						NaNO ₃	1	
						NH ₄ Cl	1	
						KI	1	
						Ce ₂ (SO ₄) ₃	1	
3	NH ₃	63	98	-	-	Ce ₂ (SO ₄) ₃	1	2
4	KI	17	26	1	2	NaNO ₃	37	72
						KNO ₃	7	
						NH ₃	2	
5	Ce ₂ (SO ₄) ₃	57	89	1	2	NaCl	3	9
						KI	2	
						KClO ₃	1	
6	50°C	54	84	1	2	40°C	5	14
						20°C	2	
						30°C	1	
						28°C	1	
7	60°C	36	56	16	25	70°C	6	19
						50°C	3	
						150°C	1	
						110°C	1	
						75°C	1	
8	a	46	72	15	23	80 g water	1	5
	b					40 g water	1	
	c					10 g water	1	
9	%16,7	16	25	8	12	10 g KClO ₃	1	2
						100 g	1	
						40	1	
10	KCl and NaCl	46	72	6	9	30	1	19
						%20	33	
						%25	4	
						%60	1	
						%50	1	
10	KCl and NaCl	46	72	6	9	%40	1	19
						None of the matter	4	
						KNO ₃ and KCl	3	
						KClO ₃ and Ce ₂ (SO ₄) ₃	1	
						NaCl, KCl and NH ₃	1	
10	KCl and NaCl	46	72	6	9	KClO ₃ and NH ₄ Cl	1	19
						Ce ₂ (SO ₄) ₃	2	

In Question 8, gifted students were asked to determine the amounts of solvent, solute, and solution in a saturated KClO₃ solution at a given temperature by interpreting the data on the graph. For part (a), which involved identifying the amount of solvent, 72% of the participants answered correctly, 5%

answered incorrectly, and 23% left the question blank. This suggests that some gifted students had difficulty reading the information provided on the graph axes. For part (b), which required determining the amount of solute, 71% of the gifted students responded correctly, 2% incorrectly, and 27% left the question unanswered. This again indicates challenges in interpreting the graphical data. For part (c), which involved calculating the total amount of solution, 64% of the gifted students answered correctly, 5% incorrectly, and 31% did not respond. This finding suggests that some participants were unable to provide the correct answer to this part because they could not accurately identify the quantities required in parts (a) and (b). In Question 9, the gifted students were asked to express the amount of dissolved substance as a percentage by mass by reading the solubility value of KClO_3 corresponding to a given temperature from the solubility axis. This question was answered correctly by 25% of the participants, incorrectly by 63%, and left blank by 12%. An analysis of the incorrect responses—given by the majority of participants—revealed that 33 gifted students answered “20%.” Although these participants correctly read the amount of dissolved substance (20 g) from the solubility axis, they were unable to accurately convert this information into percentage concentration by mass. This finding suggests that the gifted students either held misconceptions about the concept of percentage concentration by mass or experienced difficulty transforming graphical data into another representational form. In Question 10, the gifted students were asked to identify the substances with equal solubility values at a given temperature by determining the intersection points of the graph curves. This question was answered correctly by 72% of the participants, incorrectly by 19%, and left blank by 9%.

The descriptive results about participants' graph interpretation skills, assessed through Questions 11–20 in the first part of the test, are presented in Table 3. In Question 11 of the test, the gifted students were asked to use the graph to determine the solubility of NH_4Cl (in 100 grams of water) at a given temperature, then convert this value to its solubility in 50 grams of water. The majority of gifted students (83%) answered correctly, 12% answered incorrectly, and 5% left the question blank (Table 3). An analysis of the incorrect responses revealed that some participants were able to locate the solubility value on the graph but failed to correctly convert it to the corresponding amount in 50 grams of water. Others, however, were unable to obtain the correct value due to difficulties in accurately reading the graph. In Question 12, the gifted students were asked to read the solubility value of KNO_3 (in 100 grams of water) from the graph at a given temperature, convert this value to its solubility in 50 grams of water, and interpret the provided amount of KNO_3 (35 grams) in terms of the solution's saturation status. This question was answered correctly by 80% of the participants, incorrectly by 14%, and left unanswered by 6%. Among those who answered incorrectly, the majority (7 students) classified the solution as supersaturated. Examination of their answer sheets indicated that these participants likely read values for substances other than KNO_3 from the graph, which led them to incorrect conclusions. In Question 13, it was required the gifted students to calculate the amount of KNO_3 in a saturated solution at a given temperature using the graph and to compare the calculated value with the provided amount to determine the saturation state of the solution. This item was answered correctly by 25% of the participants, incorrectly by 69%, and left blank by 6%. Among those who answered incorrectly, 58% identified the solution as supersaturated. This result suggests that many gifted students hold misconceptions regarding the concept of supersaturation. Specifically, they appeared to believe that adding a solute in excess of the solubility limit automatically results in a supersaturated solution—a misconception also observed at a higher frequency in the responses to the ninth statement of the third part of the test. In Question 14 of the test, the gifted students were asked to interpret the relationship between solubility and temperature for the substances shown in the graph and to identify which substances would decrease in solubility as temperature increased—thereby leading to crystallization in the container. Only 5% of the participants answered this question correctly, while the vast majority (87%) answered incorrectly and 8% left it blank. An analysis of the incorrect responses revealed that 49 participants identified NH_3 (ammonia gas) as a substance likely to crystallize, in addition to the correct answer, $\text{Ce}_2(\text{SO}_4)_3$ (cerium sulfate). This pattern suggests that although many gifted students were able to correctly interpret the relationship between solubility and temperature from the graph, they failed to consider the physical state of the substance whose solubility decreased with increasing temperature.

Table 3. Frequencies and percentages of responses to graph interpretation questions

Questions	True Response	TRUE		BLANK		Students Responses	FALSE	
		f	%	f	%		f	%
11	25 g	53	83	3	5	50 g 10 g 40 g	4 2 2	12
12	Unsaturated Solution	51	80	4	6	Supersaturated Saturated	7 2	14
13	Saturated Solution	16	25	4	6	Supersaturated Unsaturated	39 5	69
14	Ce ₂ (SO ₄) ₃	3	5	5	8	Ce ₂ (SO ₄) ₃ and NH ₃ Ce ₂ (SO ₄) ₃ , NaCl and NH ₃ KNO ₃ and NaNO ₃ KClO ₃	49 3 2 2	87
15-A	Supersaturated	54	84	5	8	Unsaturated	5	8
15-B	Saturated	60	94	3	5	Unsaturated	1	1
15-C	Unsaturated	56	88	4	6	Supersaturated	4	6
16	<u>Exothermic</u> [Ce ₂ (SO ₄) ₃ and NH ₃] <u>Endothermic</u> [KNO ₃ , NaNO ₃ , KCl, NaCl, KI, NH ₄ Cl and KClO ₃]	49	76	3	5	Confusing endothermic with exothermic	12	19
17	24 g KClO ₃	5	8	15	23	40 g 60 g 80 g Since it's saturated, it can't dissolve.	25 3 2 14	69
18	50°C	28	44	15	23	90°C 80°C 60°C 40°C	4 7 5 5	33
19	8 g	38	59	12	19	20 g 16 g 10 g	4 6 4	22
20	250 g	41	64	12	19	500 g 160 g 80 g	5 3 3	17

In Question 15, the gifted students were asked to classify the solutions of a given substance at three different points on the graph as saturated, unsaturated, or supersaturated. The majority of participants (94%) correctly identified the point on the curve (Point B) as representing a saturated solution. Similarly, 84% correctly identified the point below the curve (Point C) as unsaturated, and 88% correctly identified the point above the curve (Point A) as supersaturated. However, a small proportion of participants (8%, 1%, and 6%, respectively) provided incorrect classifications for the terms supersaturated, saturated, and unsaturated. These errors likely stem from participants' difficulties in accurately reading and interpreting the graph. In Question 16, the gifted students were asked to classify the solubility processes of the substances shown in the graph as endothermic or exothermic by interpreting the relationship between solubility and temperature. A total of 76% of participants correctly classified the processes, while 19% provided incorrect classifications, and 5% did not respond. Examination of the incorrect responses indicated that some gifted students reversed

the meanings of the two terms—labeling endothermic processes as exothermic and vice versa. This finding suggests that some participants lacked a clear conceptual understanding of the terms endothermic and exothermic, leading to confusion in their graphical interpretations. In Question 17 of the test, the gifted students were required to perform mathematical operations by correlating the given data with the data presented in the graph and to interpret the results obtained. Only 8% of the participants answered this question correctly, while 69% answered incorrectly and 23% did not respond. Analysis of the incorrect responses revealed that a large proportion of the gifted students (25 participants) provided the same incorrect answer—40 grams. This pattern may be attributed to their misinterpretation of the term percentage by mass. This interpretation is further supported by the high rate of incorrect responses (63%) observed in Question 9 (see Table 2), which also involved expressing the amount of dissolved substance as a percentage by mass concentration. In addition, a wide variety of incorrect answers were recorded, suggesting that many participants struggled to apply the correct procedural steps necessary to solve the problem. In Question 18, the gifted students were asked to establish a proportional relationship between the given data and the information presented in the graph and to interpret the curve accordingly. Forty-four percent of the participants answered this question correctly, 33% answered incorrectly, and 23% did not respond. A closer examination of the incorrect answers indicated that many gifted students were unable to correctly formulate the mathematical equation required to solve the problem and had difficulty accurately interpreting the graph curve. In Question 19, the gifted students were expected to determine the solubility value at a given temperature from the graph and to perform the necessary mathematical operations to calculate the desired quantity. This question was answered correctly by 59% of the participants, incorrectly by 22%, and left blank by 19%. Examination of the incorrect responses revealed that many participants experienced difficulties in relating the provided data to the graph and converting this information into appropriate mathematical operations. In Question 20, the gifted students were asked to use the data presented in the graph to calculate the required quantity through mathematical operations. This question was answered correctly by 64% of the participants, incorrectly by 17%, and left unanswered by 19%. Analysis of the incorrect responses showed that the participants who failed to solve this question had similar difficulties in associating the given data with the graphical information and in translating it into the necessary mathematical calculations.

Questions 21–25 in the second part of the test focused on gifted students' ability to perform interpolation and extrapolation using the data presented in the graph. The results derived from the evaluation of their responses are summarized in Table 4.

Table 4. Frequencies and percentages of responses to interpolation and extrapolation questions based on graph data

Question	True Response	TRUE		BLANK		FALSE		
		f	%	f	%	Students Responses	f	%
21	KNO ₃	82	86	8	8	KClO ₃	4	6
						KNO ₃ and KCl	2	
22	NH ₃ and KClO ₃	82	86	7	7	KNO ₃ and NH ₃	4	7
						NaCl and NH ₃	3	
23	35°C	65	68	12	12	34°C	10	20
						40°C	9	
24	72 – 73 °C	72	75	8	8	136 °C	6	17
						135 °C	6	
						75 °C	2	
						71 °C	2	

Table 4 (Continued). Frequencies and percentages of responses to interpolation and extrapolation questions based on graph data

Question	True Response	TRUE		BLANK		FALSE		
		f	%	f	%	Students Responses	f	%
25	153 – 155 g	22	23	15	16	160 g	24	61
						156 g	4	
						150 g	4	
						145 g	3	
						0 g	24	

As shown in Table 4, in Question 21 of the test, the gifted students were asked to identify the substance whose solubility corresponded to a temperature value within the data range but not explicitly provided in the graph. The vast majority (86%) answered this question correctly, while 6% responded incorrectly and 8% left it unanswered. Similarly, in Question 22, the gifted students were again required to determine the substance whose solubility corresponded to a temperature value within the range but not among the specific data points presented. The same proportion (86%) answered correctly, while 7% either gave incorrect responses or left the question blank. In Question 23, the task involved determining the temperature value for a given solubility of a substance using the data shown in the graph. Most participants (68%) successfully calculated the correct temperature value, whereas 20% answered incorrectly and 12% provided no response. Question 24 asked the gifted students to determine, based on the graph, the temperature at which two substances had equal solubility values within the data range. A majority (75%) calculated this temperature correctly, while 17% answered incorrectly and 8% did not respond. The incorrect answers indicated that some participants struggled with accurately reading and comparing data on the graph. Finally, Question 25 assessed the participants' extrapolation skills, requiring them to use data beyond the range presented in the graph. Only a small proportion (23%) answered correctly, whereas 61% responded incorrectly and 16% left the question blank. These findings suggest that the gifted students' extrapolation skills were notably weaker than their interpolation skills.

In the second part of the test, the gifted students' responses to the questions from the first part and to the statements in this section were analyzed together by comparing their frequencies and percentages across the eight categories outlined in Table 1. The combined results are presented in Table 5.

Table 5. Frequencies and percentages of statements and their corresponding question categories

Statement (S)/Question (Q)	CATEGORIES* (n=64)															
	TC		FI		TI		FC		BC		BI		TB		FB	
Matching	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
8.S / 7.Q	37	58	-	-	14	22	-	-	-	-	-	-	13	20	-	-
2. S / 8a. Q	43	67	-	-	9	14	4	6	1	2	-	-	4	6	3	5
2. S / 8b. Q	43	67	-	-	9	14	4	6	-	-	1	2	4	6	3	5
1. S / 8c. Q	40	62	-	-	16	25	3	5	-	-	-	-	5	8	-	-
6. S / 9. Q	17	27	3	5	40	62	-	-	-	-	-	-	4	6	-	-
10. S / 12. Q	49	76	1	2	9	14	-	-	-	-	-	-	5	8	-	-
8. S / 13. Q	14	22	-	-	45	70	-	-	-	-	-	-	5	8	-	-
11. S / 14. Q	-	-	25	39	33	51	-	-	-	-	-	-	5	8	1	2
9. S / 15a. Q	18	28	3	5	2	3	39	61	-	-	-	-	-	-	2	3
8. S / 15b. Q	60	94	-	-	-	-	-	-	-	-	-	-	4	6	-	-
10. S / 15c. Q	55	86	-	-	4	6	1	2	-	-	-	-	4	6	-	-
4. S / 16. Q	43	67	7	11	7	11	4	6	-	-	-	-	3	5	-	-
5. S / 16. Q	35	55	4	6	10	15	12	19	-	-	-	-	2	3	1	2
6. S / 17. Q	5	8	3	5	42	65	-	-	-	-	-	-	14	22	-	-

*TC: True Statement - Correct Answer, FI: False Statement - Incorrect Answer, TI: True Statement - Incorrect Answer, FC: False Statement - Correct Answer, BC: Blank - Correct Answer, BI: Blank - Incorrect Answer, TB: True Statement - Blank, FB: False Statement - Blank

Detailed interpretations were made for the TI and TB categories, which represent instances where gifted students demonstrated correct conceptual understanding of the topic but provided incorrect or blank answers due to insufficient skills in reading and interpreting graphs. When examining the percentage of cases in which participants answered the conceptual statement correctly in the third part of the test but responded incorrectly to the corresponding graph-related question in the second part, the TI category percentages ranged from 3% to 70%. Similarly, the TB category percentages ranged from 3% to 22%. The high percentages observed in the TI category suggest that many gifted students encountered considerable difficulties with graph reading and interpretation. Questions with particularly high TI percentages included items 9 (62%), 13 (70%), 14 (51%), and 17 (65%). In these questions, errors primarily stemmed from students' struggles with interpreting graphical data, despite their accurate conceptual understanding. A comparable pattern was observed for the TB category, though the percentages were generally lower. Notably higher TB rates were found in questions 17 (22%) and 7 (20%), further highlighting areas where participants faced challenges in connecting their conceptual knowledge with graph interpretation skills. Furthermore, the comparatively lower percentages in the FI category relative to the TI category for these items (Questions 9, 13, 14, and 17) also suggest that the gifted students' graph-interpretation skills in these questions were insufficient. The high percentages observed in the TC category in Table 5 (ranging from 8% to 94%) are not unexpected, as graph interpretation is strongly linked to the accurate assimilation of the underlying conceptual knowledge. Notably, Question 14 is the only item in this group where the TC category was recorded as 0%. This indicates that the gifted students lacked a sufficient understanding of Statement 11, which corresponds to this question.

DISCUSSION, CONCLUSION, and RECOMMENDATIONS

This study aimed to assess gifted students' graph reading and interpretation skills using a two-part test. The test items were designed in alignment with the research objectives, and therefore the discussion is organized under this heading.

Gifted Students' Levels of Graph Reading and Interpretation

An analysis of the graph-reading questions in the first section of the test (Questions 1–10) indicates that the gifted students generally experienced minimal difficulty with basic graph reading. A closer examination of the data in Table 2 shows that, except for three items (Questions 4, 7, and 9), the percentage of correct responses was well above average, ranging from 56% to 98%. In contrast to this overall positive trend, incorrect response rates for Questions 4 and 9 were notably high, at 72% and 63%, respectively. These results suggest that gifted students struggled with the graph-reading skills required for these items. Although the false rate for Question 7 was not as high as for Questions 4 and 9, the proportion of blank responses was relatively high. When false and blank responses are combined, the total reaches 44%, which is substantial and cannot be disregarded. Because this item required a two-step solution involving mathematical operations, the gifted students' errors likely stemmed from insufficient mathematical proficiency. As noted in the relevant literature (e.g., Parmar & Signer, 2005; Planinic et al., 2019; Stavridou & Kakana, 2008), mathematical competence plays a critical role in drawing, reading, and interpreting graphs; thus, learners with weaker mathematical skills often have difficulty engaging successfully with graphic tasks.

Analysis of the graph-interpretation questions in the first section of the test (Questions 11–20) suggests that gifted students also did not experience major difficulties with graph interpretation overall. A detailed review of the data in Table 3 shows that, apart from four questions (Questions 13, 14, 17, and 18), correct response rates ranged from 59% to 94%. However, incorrect response rates were unusually high for Questions 13, 14, and 17—69%, 87%, and 69%, respectively. Question 13 required conceptual understanding of supersaturation. Although most gifted students correctly answered the statement measuring their conceptual knowledge of supersaturation in the second part of the test, many still performed poorly on the graphical interpretation task. At first glance, this may appear contradictory. However, this finding can be explained by the presence of misconceptions regarding supersaturated solutions. The literature frequently reports that learners at all levels hold

misconceptions about solutions (e.g., Çalık & Ayas, 2004; Suparman et al., 2024). Individuals with entrenched misconceptions may sometimes answer conceptual questions correctly while still applying incorrect reasoning in practice. Marek's (1986) well-known phrase, "They misunderstand, but they'll pass" captures this phenomenon effectively. As Brasell (1990) notes, gifted students who hold misconceptions about supersaturation may struggle to interpret graphs representing these concepts. A similar pattern was observed in Question 14. Although most gifted students answered Statement 11 correctly, which assessed the scientific knowledge needed to solve the question, many still answered the question incorrectly because they failed to consider the physical states of matter. In contrast, the errors in Question 17 appear to have resulted primarily from difficulties in interpreting the graph rather than from conceptual misunderstandings. The same issue was evident in Question 18. Although the percentage of false responses for Question 18 (33%) was lower than for the other problematic items (Questions 13, 14, and 17), when combined with the percentage of blank responses (23%), the total reaches 56%, which is above the expected level. These results suggest that the gifted students' incorrect or missing responses were largely due to insufficient graph-interpretation skills.

When graph-reading and graph-interpretation skills are considered together, it becomes clear that the gifted students' graph-reading skills are stronger than their graph-interpretation skills. Such a finding is, in fact, expected. As noted earlier, graph interpretation is a more complex skill that requires attention to multiple components. Two key components are conceptual understanding (Brasell, 1990; Stefanel, 2019) and mathematical proficiency (Parmar & Signer, 2005; Planinic et al., 2019; Stavridou, & Kakana, 2008). Naturally, individuals who lack sufficient conceptual or mathematical knowledge cannot be expected to interpret graphs effectively.

Gifted Students' Levels of Interpolation and Extrapolation Using Graphical Data

An analysis of the questions in the first part of the test (Questions 21–25), which assessed interpolation skills using graphical data, indicates that the gifted students demonstrated generally good proficiency in interpolation and did not experience major difficulties in this area. As shown in the detailed analysis in Table 4, the percentage of participants who correctly answered Questions 21, 22, 23, and 24 was above average, ranging from 68% to 86%. However, this positive trend did not extend to extrapolation. In contrast to interpolation, the gifted students' performance on the extrapolation task was well below average. Specifically, 61% of the participants answered Question 25, which involved extrapolation, incorrectly. When this figure is combined with the percentage of those who left the question unanswered, the total reaches 77%, a notably high rate. This outcome may be attributed to the fact that extrapolation is regarded as a more advanced cognitive skill. Extrapolation requires estimating values beyond the existing data range (Watson et al., 2024). Moreover, it is often applied not only to infer values not shown on a graph but also in contexts where direct experimental determination is impossible—for instance, when calculating Kelvin temperature as the absolute temperature of ideal gases (Zeren, 1994, p. 153). As such, extrapolation represents a higher-order reasoning skill frequently employed by scientists (Watson et al., 2024).

Relationship Between Gifted Students' Conceptual Understanding and Graphical Skills

According to the analysis (Table 5), the high percentages observed in the TC category for several questions—specifically, question 7 (58%) on graph reading; questions 8(a) (67%) and 8(c) (62%) on graph interpretation; question 12 (76%) on graph interpretation; questions 15(b) (94%) and 15(c) (86%) on graph interpretation; and question 16 (67%)—indicate that the gifted students were highly successful in both their conceptual understanding of solubility and their ability to read and interpret the related graphical questions. This finding suggests a strong connection between conceptual knowledge and graphical skills. This outcome is, in a sense, expected, as most changes represented in solubility graphs inherently involve conceptual knowledge about the topic. The finding aligns with numerous studies in the literature (e.g., Brasell, 1990; Gültepe, 2016; Stefanel, 2019). For example, Gültepe (2016) concluded that "students with strong conceptual understanding demonstrate strong graphical skills, while those with weak conceptual understanding perform poorly in graphical tasks." Brasell (1990) extended this view further, asserting that not only individuals with insufficient conceptual understanding but also those with misconceptions tend to struggle with graphical tasks. In

summary, there is clear evidence of a positive relationship between conceptual understanding and graphical skills. However, the study also revealed that even when gifted students possessed accurate conceptual knowledge, they sometimes answered graph-related questions incorrectly (Category TI) or left them unanswered (Category TB), suggesting difficulties with graph reading and interpretation. As shown in Table 5, the proportions for these categories ranged from 3% to 70% for TI and from 3% to 22% for TB. Questions 9 (62%), 13 (70%), 14 (51%), and 17 (65%)—which showed high percentages in the TI category—were associated with graph reading (question 9) and graph interpretation (questions 13, 14, and 17). Although the gifted students understood the conceptual information in these graphs, they made errors due to difficulties in reading and interpreting the visual data. Similarly, when the TI and TB categories were combined, relatively high percentages were also observed for question 7 (42%) and question 8(a) (20%), 8(b) (20%), and 8(c) (33%) on graph reading, as well as for questions 12 (22%) and 16 (18%) on graph interpretation. These findings indicate that gifted students faced certain challenges in graph reading and interpretation, regardless of their conceptual understanding. This result is consistent with previous research (Bayazit, 2011; Gültepe, 2016; Okur & Güngör Seyhan, 2025; Taşar et al., 2002). Bayazit (2011) highlighted this issue with a particular example. He noted that students struggled to interpret graphs even in areas where they clearly possessed the necessary mathematical knowledge, for instance, understanding the simple relationship between the side length of a square and its area. This observation underscores that students' challenges with even the most basic graphs point to fundamental weaknesses in their graph-reading and interpretation skills. Similar findings have also been reported in studies across different disciplines, which compare students' performance on conceptual versus graphical questions (e.g., Coştu, 2023; Coştu, 2007; Kurnaz, 2013). These studies found that while students often performed well on conceptual questions targeting the same learning outcomes, their performance on corresponding graphical questions was notably lower. The results of these studies support the conclusions drawn from the present research.

In summary, this study found that gifted students' graph reading skills were generally stronger than their graph interpretation skills. Additionally, their performance in extrapolation tasks was lower than in interpolation tasks. Finally, although a positive relationship between conceptual understanding and graphical skills was observed, it was evident that gifted students' difficulties often stemmed from insufficient graphical skills rather than from a lack of conceptual knowledge.

Implementation and Recommendations

Based on the findings of this study, several implications emerge for instructional practice, curriculum design, and future research in the education of gifted students. Although gifted learners often demonstrate strong graph-reading abilities, their difficulties with graph interpretation and especially with extrapolation highlight the need for explicit and systematic instruction in advanced graphical reasoning skills. This aligns with prior research showing that graph interpretation is a complex skill requiring conceptual, mathematical, and representational competence (Brasell, 1990; Parmar & Signer, 2005; Planinic et al., 2019), and that even high-achieving learners may struggle with these higher-order graphical tasks (Bayazit, 2011; Gültepe, 2016; Stefanel, 2019). Firstly, graph interpretation should be integrated more intentionally into science and mathematics instruction within gifted education programs such as BİLSEM. Teachers should incorporate activities that require students not only to read values from graphs but also to make predictions, identify trends, and justify interpretations using conceptual and mathematical reasoning. Such instructional practices are consistent with constructivist principles emphasizing active engagement, multiple representations, and data-driven reasoning (e.g., Okur & Güngör Seyhan, 2025). Laboratory-based tasks that involve real-time data generation (e.g., MBL technologies) may help strengthen these skills by making abstract relationships more concrete. Prior studies have shown that real-time graphing environments support students' conceptual and graphical understanding of scientific phenomena (e.g., Brasell, 1987). Secondly, instruction should explicitly target common misconceptions identified in this study—such as misunderstandings about supersaturation or the physical states of substances—and connect these concepts directly to graphical representations. Misconceptions about solutions and related chemical concepts are widely documented in the literature (e.g., Çalık & Ayas, 2004; Suparman et al., 2024),

and researchers emphasize that these misconceptions can persist even when students correctly answer conceptual items (Marek, 1986). Conceptual change strategies, including guided inquiry, analogies, and discrepant events, may support deeper understanding and correct underlying misconceptions. Such approaches are recommended in science education research for promoting meaningful learning and correction of entrenched misconceptions. Thirdly, teachers working with gifted students should provide structured learning opportunities that gradually shift from interpolation tasks toward more complex extrapolation tasks. Scaffolding techniques, such as breaking down extrapolation problems into smaller steps or using multiple representations (tables, equations, and verbal reasoning), may help students develop confidence and flexibility in handling data beyond the presented range. This recommendation is supported by studies showing that extrapolation involves higher-order reasoning and is more challenging than interpolation for learners at all levels (e.g., Watson et al., 2024). Fourthly, professional development programs for BİLSEM teachers should include training on how to teach graph interpretation as a higher-order thinking skill. Since the results indicate that difficulties persist even when conceptual knowledge is strong, teacher training should focus on pedagogical approaches that strengthen students' ability to integrate mathematical reasoning with visual data interpretation. Prior work shows that innovations in curricula often fail due to insufficient teacher preparation and lack of pedagogical content knowledge needed to guide targeted activities effectively. Strengthening teachers' ability to teach graph interpretation would therefore directly support the development of students' scientific literacy. This is consistent with AAAS (1993) criteria that emphasize the importance of graph construction, interpretation, and critique as essential components of scientific literacy. Finally, future studies should explore the effectiveness of targeted instructional interventions—particularly those using inquiry-based or technology-enhanced learning environments—on improving gifted students' graphical competencies. Longitudinal research could further examine how these skills develop over time and which instructional practices best support sustained improvement. Inquiry-based and technology-supported instructional models have been shown to enhance students' achievement and graphical reasoning (Gültepe, 2016; Karatay et al., 2024), suggesting promising directions for further empirical investigation.

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Ethics and Conflict of Interest

This study was reviewed and approved by the Yildiz Technical University, Social and Human Sciences Research Ethics Committee (Meeting Date: 02.05.2025, Meeting Number: 2025.05). The committee confirmed that this research, conducted within a Science and Art Center (SAC), is exempt from formal institutional review requirements, as such in-class studies are covered under institutional regulations. All procedures were carried out in accordance with the Declaration of Helsinki and relevant institutional and national guidelines. This research was conducted in a classroom setting within SAC. According to institutional regulations, such in-class action studies are exempt from formal ethics committee review. The author declares no competing interests.

Data Availability

The data that support the findings of this study are available on request from the author.

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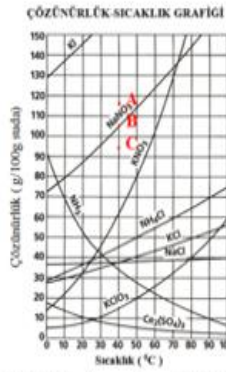
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APPENDIX

Appendix 1: Two-part test as the data collection tool used in the study.



BÖLÜM I

Aşağıda verilen soruları yandaki çözünürlük-sıcaklık grafiğini kullanarak cevaplayınız.

1. Grafiğe göre çözünürlüğü sıcaklık değişiminden en az etkilenen madde hangisidir?
2. Grafiğe göre sıcaklık artışı ile çözünürlüğünde en büyük artış gözlenen madde hangisidir?
3. Grafiğe göre sıcaklık artışı ile çözünürlüğünde en büyük düşüş gözlenen madde hangisidir?
4. 30 °C'de en büyük çözünürlüğe sahip olan madde hangisidir?
5. 30 °C'de en küçük çözünürlüğe sahip olan madde hangisidir?
6. 100 gram suda hangi sıcaklık değerinde 20 gram KClO_3 çözünür?
7. 10 °C'de 100 gram suya 130 gram KNO_3 ilave edilerek hazırlanan çözeltiyi doymuş hale getirebilmek için sıcaklık kaç °C arttırılmalıdır?

8. 50 °C'de hazırlanmış doymuş KClO_3 çözeltisinde yer alan çözücü, çözünen ve çözelti miktarlarını yazınız.

a) Çözücü : b) Çözünen : c) Çözelti :

9. 50 °C'de hazırlanmış doymuş KClO_3 çözeltisi kütlece % kaçlıktır?

10. 40 °C'de hangi maddelerin çözünürlükleri aynıdır?

11. 50 °C'de 50 gram suda kaç gram NH_4Cl çözünür?

12. 50 °C'de 50 gram suya 35 gram KNO_3 ilave edilirse çözeltinin doymuşluğu için ne söylenebilir?

13. 50 °C'de 100 gram suya 30 gram KClO_3 ilave edilirse çözeltinin doymuşluğu için ne söylenebilir?

14. Grafiğe görülen bütün maddelerin aynı kaplar içerisinde 20 °C'de doymuş çözeltileri hazırlanıyor. Daha sonra hazırlanan çözeltilerin sıcaklığı 40 °C'ye çıkartılıyor. Hangi madde ya da maddelerin bulunduğu kaplarda kristalleşme meydana gelir?

15. Grafiğe 40 °C'de 100 gram suda NaNO_3 katısı çözülerek hazırlanmış A, B ve C noktalarındaki üç farklı durum için çözelti içinde çözünmüş madde miktarları bakımından sınıflandırınız.

Çözelti	Aşırı doymuş çözelti	Doymuş çözelti	Doymamış çözelti
A			
B			
C			

16. Grafiğe yer alan bileşiklerin sudaki çözünürlüklerini endotermik ve ekzotermik olarak sınıflandırınız.

Bileşik	Ekzotermik	Endotermik	Bileşik	Ekzotermik	Endotermik
KI			NH_4Cl		
NaNO_3			$\text{Ce}_2(\text{SO}_4)_3$		
KNO_3			KCl		
NH_3			KClO_3		
NaCl					

17. 80 °C'de kütlece % 20'lik 200 gram KClO_3 çözeltisi daha kaç gram KClO_3 çözebilir?

18. 90 °C'de 400 gram suda 200 gram NH_4Cl katısı çözülerek hazırlanan çözelti soğutulmaya bırakılırsa, ilk çökme hangi sıcaklıkta başlar?

19. 50 °C'de 40 gram su içine kaç gram KClO_3 katısı eklenirse, tamamı çözünür?

20. 50 °C'de 200 gram KNO_3 katısı çözebilmek için kaç gram su kullanılmalıdır?

21. Hangi maddenin sudaki çözünürlüğü 13 °C civarında 25g/100g su'dur?

22. Hangi maddelerin 57 °C'deki çözünürlükleri aynıdır?

23. Hangi sıcaklıkta NaNO_3 katısının çözünürlüğü 100g/100g sudur?

24. 30 °C'de KI'ın sudaki çözünürlüğü kaç g/100 g sudur?

25. Hangi sıcaklıkta KNO_3 ve NaNO_3 bileşiklerinin sudaki çözünürlükleri aynıdır?

BÖLÜM II

Aşağıda verilen ifadelerin doğru ya da yanlış olduklarını belirtiniz.

İFADELER	Doğru	Yanlış
1. Bir madde taneceklerinin, başka bir madde tanecekleri arasında homojen olarak dağılması olayına çözünme , oluşan homojen karışıma ise çözelti denir.		
2. Bir çözeltinin bileşenlerinden genellikle miktardan fazla olana çözünen , miktardan az olana ise çözücü adı verilir.		
3. Çözünürlük , sabit sıcaklık ve basınçta 100 gram çözücü içinde çözünebilecek maksimum madde miktarıdır.		
4. Sıvı içinde çözünmesi ekzotermik olan katıların çözünürlüğü sıcaklık arttıkça artar, çözünmesi endotermik olan katıların ise sıcaklık arttıkça azalır.		
5. Gazların çözünürlüğü ekzotermik olduğundan, tüm gazların çözünürlüğü sıcaklık artışı ile azalır.		
6. 100 gram çözeltide bulunan çözünmüş maddenin gram cinsinden miktarına kütlece yüzde derişim denir.		
7. 0 °C'de bütün maddelerin çözünürlüğü aynıdır.		
8. Belli bir sıcaklık ve basınçta çözücünün çözebileceği kadar çözünen madde içeren çözeltiye doymuş çözelti denir.		
9. 20 °C'de 100 gram suda maksimum 35 gram NaCl katısı çözünebilmektedir. 20 °C'de 100 gram suya 40 gram NaCl katısı ilave edilirse aşırı doymuş çözelti oluşur.		
10. Bir çözeltide doymuşluk miktarının altında madde çözünmüş ise bu çözeltiye doymamış çözelti denir.		
11. Çözünürlüğü sıcaklık artışıyla azalan bütün maddelerin doymuş haldeki çözeltileri soğutulursa çözelti içinde bulunan katıların dibinde kristalleşme meydana gelir.		
12. Belirli bir sıcaklıkta bir katının sıvı içindeki doymamış çözeltisini doymuş hale getirmek için ya yeterince çözünen madde eklenir ya da yeterince çözücü buharlaştırılır.		