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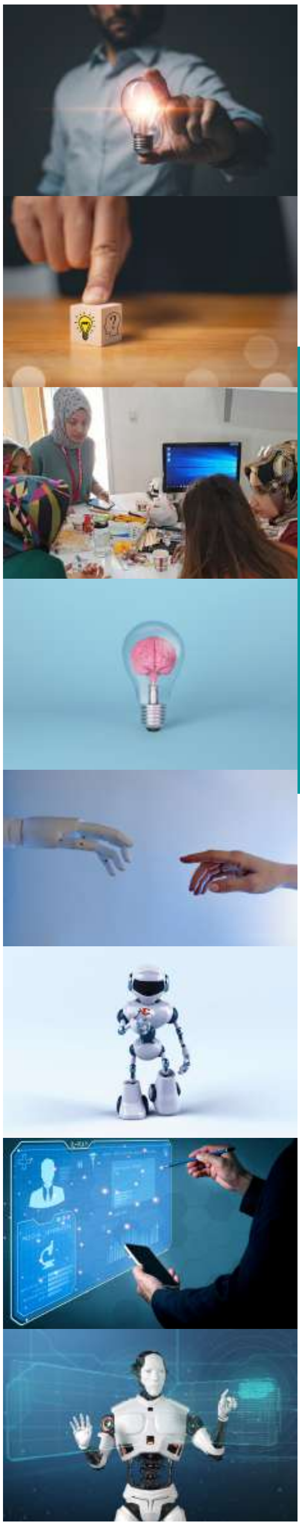

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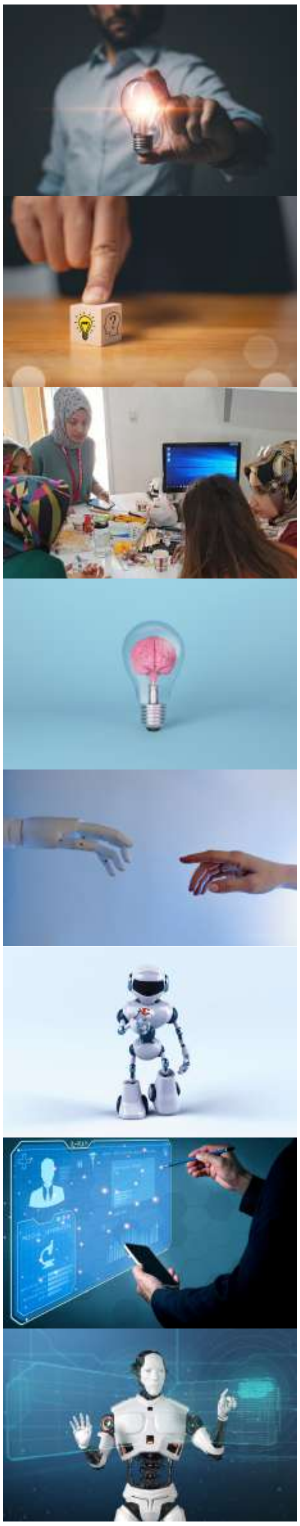

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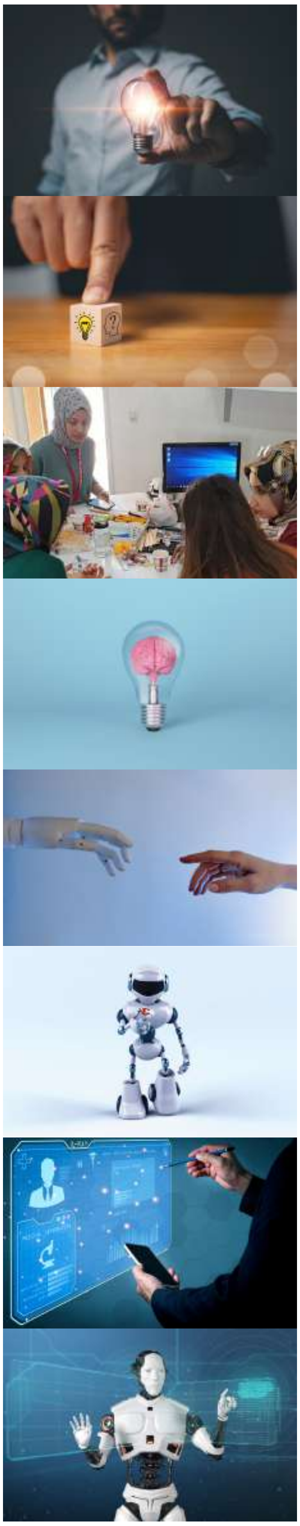

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Teacher Candidates' Metaphorical Perceptions of ChatGPT

Ahmet Aykan[1].

Abstract

This study aims to explore teacher candidates' metaphorical perceptions of ChatGPT, a language model based on artificial intelligence, by examining the attitudes, expectations, and concerns they hold toward this emerging technology in a comprehensive manner. Adopting a phenomenological approach from the qualitative research tradition, the study included 220 senior-year teacher candidates enrolled in a Faculty of Education at a university. As the data collection tool, a Metaphor Generation Form was developed, prompting participants to complete the statement "ChatGPT is like … because …," followed by open-ended questions about why they chose these metaphors. Results of the content analysis reveal that participants most frequently characterize ChatGPT positively through metaphors such as a "Knowledge Repository" and an "Assistant/Guide." Conversely, metaphors like "Black Box/Unfathomable Power" highlight concerns regarding reliability and transparency in this technology. Furthermore, the theme of a "Magic Wand/Miracle" signifies teacher candidates' high expectations for ChatGPT. When examining the rationale behind the metaphors, it becomes clear that, alongside positive factors like speed and variety, there are notable reservations related to ethics and academic integrity. According to a classification of positive, negative, and neutral attitudes, half of the participants view ChatGPT as beneficial and supportive, whereas roughly one-third remain skeptical or negative due to reliability and ethical issues. Demographic variables (e.g., academic department, familiarity with technology) also shape these metaphorical perceptions; notably, those with higher technological literacy adopt a more optimistic outlook on ChatGPT. These findings suggest that while teacher candidates consider both the potential benefits and ethical-technical risks of AI-based tools like ChatGPT in educational contexts, additional pedagogical and ethical frameworks are necessary for successful integration. The study underscores the importance of AI literacy in future teacher education curricula and suggests that practical coursework and ethical-awareness activities could foster a more informed and responsible stance toward AI technologies.

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ChatGPT, teacher candidates, metaphor analysis, artificial intelligence, educational technologies.

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Introduction

Rapid developments in artificial intelligence (AI) have accelerated digitalization and technological transformation within education systems (Russell & Norvig, 2010). In this context, AI models trained on large datasets bring novel perspectives to teaching and learning through data-processing and interpretation capabilities (Baker & Yacef, 2009). Notably, extensive language models such as ChatGPT have come to the forefront for their capacity to guide users, provide answers, and generate diverse outputs, from academic research to everyday information queries (Brown et al., 2020). By analyzing complex questions and responding in a comparatively natural linguistic flow, ChatGPT diverges from traditional chatbots and is thought to offer teachers and students a dynamic learning environment (Zhai, 2022).

Teacher candidates' attitudes and perceptions concerning the use of technology in their future professional practices directly influence the quality of classroom instruction (Koehler & Mishra, 2009). Indeed, effectively employing technology for pedagogical aims relates closely to the cognitive and affective processes teacher candidates develop toward these tools (Davis, 1989). Advanced language models such as ChatGPT bring advantages like creating learning materials, offering rapid feedback, and producing content suited to various learning styles. However, potential pitfalls arise, including possible misinformation, ethical concerns (plagiarism, copyright infringement), and shifts in the quality of teacher-student interactions (Selwyn, 2019). Consequently, how teacher candidates perceive these AI-based tools and position them in their professional roles constitutes an essential indicator of how future educational systems will utilize technology.

Metaphor analysis serves as a valuable method for uncovering individuals' perceptions, ideas, and emotions regarding specific concepts or phenomena (Lakoff & Johnson, 1980). Within the field of educational sciences, metaphor studies are frequently employed to examine the deep-seated meanings teacher candidates assign to concepts such as "student," "teaching," or "technology" (Saban, 2008; Saban, 2009). This investigation focuses on the metaphorical perceptions teacher candidates hold about ChatGPT, aiming to understand how they conceptualize this new AI-based technology. By doing so, the study seeks to develop insights into ChatGPT's potential uses in education and identify teacher candidates' needs for technology literacy. The central objective is to answer "Which metaphors do teacher candidates employ for ChatGPT, and what rationales underpin these metaphors?" and, based on the findings, propose suggestions for future AI adoption in education. Hence, the goal is to present a detailed profile of teacher candidates' attitudes toward ChatGPT and provide crucial insights into how AI-powered technologies can be accepted and integrated into educational contexts.

Artificial Intelligence and ChatGPT

AI draws upon advances in big data, machine learning, and natural language processing, offering innovative solutions across many sectors—including education (Russell & Norvig, 2010; Baker & Yacef, 2009). Such solutions aim to enhance learning processes, deliver personalized feedback, and boost student performance (Holstein, Aleven, & Rummel, 2023). As technological infrastructure becomes more accessible, AI-based systems can be widely implemented in the educational sector.

The development of Large Language Models (LLMs) has expanded the capabilities of chatbots, enabling them to handle more complex tasks with greater versatility. Among these, ChatGPT stands out for its revolutionary progress in natural language processing (Brown et al., 2020). Distinguishing itself from traditional chatbots, ChatGPT has been trained on extensive datasets to learn the structural and semantic properties of language; it can thus produce coherent answers to sophisticated queries and generate text that approximates human output.

In education, ChatGPT holds great promise for offering students immediate and interactive feedback, assisting teachers with lesson planning, and supporting assessment processes (Henrickson, 2023). In an era of widespread remote and hybrid learning, ChatGPT's real-time interactions can enhance student motivation and personalize their learning experiences (Zhai, 2022). However, the model's inner mechanisms (algorithmic transparency), the accuracy of the generated information, and data privacy issues have raised various debates on the sustainability of using ChatGPT in education (Bender et al., 2021).

Likewise, ethical considerations tied to ChatGPT are also under scrutiny. Potential bias, copyright queries, and academic integrity guidelines raise questions about how students should use this technology, to what extent, and under what conditions (Caswell & Liang, 2022). It is thus imperative that schools and universities not only provide the infrastructure necessary for AI-based tools but also supply awareness-building and training programs directed at both teachers and students (Holstein, Aleven, & Rummel, 2023). Recent research suggests that ChatGPT can be a vital resource for developing "AI literacy" (Kim & Lee, 2023). Therefore, for ChatGPT to be successfully integrated into an educational ecosystem, ethical, pedagogical, and technological dimensions should be addressed simultaneously (Bender et al., 2021).

Teacher Candidates and ChatGPT

Teacher candidates constitute the future professional cadre of education systems, shaping how technology is utilized in classrooms (Koehler & Mishra, 2009). The presence of AI-based tools, particularly ChatGPT-like large language models, in teacher education programs exerts substantial influence on both the professional growth of these candidates and their pedagogical competencies (Kim & Lee, 2023). Understanding teacher candidates' perceptions, attitudes, and expectations about ChatGPT is thus critical for forming sound educational policies and best practices (Holstein, Aleven, & Rummel, 2023).

Existing research underscores that teacher candidates' technology adoption processes are predominantly influenced by perceived usefulness, ease of use, and self-efficacy (Davis, 1989). In the case of advanced AI tools like ChatGPT, additional elements—such as ethics, data privacy, academic honesty, and the reliability of provided information—also come into play (Henrickson, 2023). While teacher candidates acknowledge the value these technologies bring, they may worry that the ease of access provided to students could undermine their critical thinking and research skills (Zhai, 2022).

Concurrently, ChatGPT shows potential in enhancing candidates' pedagogical capacities—specifically in developing lesson content, creating alternative question banks, and producing resources tailored for different learning styles (Kim & Lee, 2023). Nevertheless, candidates are advised to cultivate a critical viewpoint regarding the accuracy and currency of ChatGPT's responses (Bender et al., 2021). Studies have indicated that teacher candidates' perceptions of ChatGPT largely depend on their level of technology literacy and prior experience with digital pedagogical tools (Holstein, Aleven, & Rummel, 2023). Candidates who possess stronger digital competencies tend to see ChatGPT more favorably, whereas those with limited experience remain uncertain about its role in the classroom and its broader impact on their professional identity (Henrickson, 2023).

Given these findings, teacher candidates should be guided to approach ChatGPT not solely as a data source but as a pedagogical tool and an adjunct to the teaching-learning process (Koehler & Mishra, 2009). Integrating more theoretical and practical courses on AI technologies within teacher education curricula, along with emphasizing ethical and critical dimensions, is recommended (Kim & Lee, 2023). Through such measures, teacher candidates can more consciously, effectively, and responsibly integrate ChatGPT and similar AI tools into their future educational practices.

Significance of Study

In contemporary education, AI-based technologies are expanding rapidly, driving a powerful transformation that may redefine the teaching profession (Holstein, Aleven, & Rummel, 2023). During this period of transition, teacher candidates' attitudes, expectations, and concerns regarding these technologies bear substantial importance, as the way they conceptualize and internalize these tools will serve as a foundation for their future classroom implementations (Kim & Lee, 2023). Models like ChatGPT hold out innovative opportunities for teacher candidates, spanning tasks such as lesson planning, assessment, resource development, and student counseling (Henrickson, 2023).

Nonetheless, apprehensions about ethical use and reliability have a decisive impact on whether candidates adopt or reject such technologies (Bender et al., 2021). Topics like academic honesty, copyright infringements, and potential bias often feature prominently in discussions about AI's educational applications, complicating the integration of these tools into learning environments. Consequently, a detailed examination of teacher candidates' perspectives on ChatGPT becomes crucial, illuminating the motivational factors, worries, and knowledge gaps that arise (Zhai, 2022).

By revealing teacher candidates' metaphorical perceptions of ChatGPT, the present study seeks to offer a more holistic perspective on the tool's educational potential. Although research on ChatGPT's use in classrooms is steadily growing, insufficient attention has been paid to the ways teacher candidates make sense of this technology and how it intersects with their pedagogical skill sets (Holstein, Aleven, & Rummel, 2023). Therefore, this investigation both fills a gap in the literature and yields practical insights into how teacher education programs might structure AI literacy.

Further, as cutting-edge technologies like ChatGPT accelerate the shift from "teacher-centered" approaches to "student-centered" or "technology-enriched" learning paradigms (Kim & Lee, 2023), developing teacher candidates' knowledge, skills, attitudes, and beliefs becomes increasingly vital (Henrickson, 2023). Findings from this study are likely to inform not just teacher training curricula but also broader educational strategies and policies. By helping teacher candidates embrace technology with both ethical awareness and pedagogical discernment, this study aims to support the next generation of teachers as effective guides in futuristic learning environments.

Purpose of the Study

As AI-driven language models rapidly gain momentum in education, the present research intends to uncover teacher candidates' perceptions of ChatGPT, along with the motivational and cautionary factors influencing these perceptions via metaphorical expressions. In an era of digital transformation, understanding how teacher candidates conceptualize and respond to new technologies—whether with acceptance, resistance, or uncertainty—holds critical importance for shaping the sustainability of technology in education (Holstein, Aleven, & Rummel, 2023; Kim & Lee, 2023). Although ChatGPT offers tools for lesson planning, assessment, and the creation of instructional materials, it also provokes discussions about information reliability, ethical principles, and academic integrity (Bender et al., 2021).

In line with this, the main research question is formulated as: "What are teacher candidates' metaphorical perceptions of ChatGPT, and which factors shape these perceptions?" To address this, the following sub-questions are proposed:

1. Which metaphors do teacher candidates use to characterize ChatGPT?
2. What reasons and themes underlie these metaphors?
3. How do metaphorical perceptions manifest as positive, negative, or neutral attitudes?
4. To what extent do demographic variables (department, year of study, familiarity with technology) reflect in teacher candidates' metaphorical perceptions of ChatGPT?

Method

Research Design

This study employs a qualitative research design to thoroughly examine teacher candidates' metaphorical perceptions of ChatGPT. Qualitative research seeks to comprehend how individuals experience and perceive a particular phenomenon or concept in depth (Creswell, 2013). Such an approach enables a comprehensive analysis of participants' feelings, thoughts, and attitudes, thereby revealing how teacher candidates conceptualize ChatGPT within their socio-cultural and personal contexts (Merriam & Tisdell, 2016).

A phenomenological strategy was chosen as the specific research design. Phenomenology focuses on participants' subjective experiences, emotions, and meaning-making processes related to a particular phenomenon (Creswell, 2013). Accordingly, this study investigates teacher candidates' "metaphorical perceptions" of ChatGPT, exploring how they position AI-based language models and what analogies they use to describe them. Using metaphor analysis in tandem with phenomenology offers an opportunity to translate participants' abstract thinking processes into concrete indicators (Yıldırım & Şimşek, 2018).

Participants

The participants in this study consist of 220 senior-year (fourth-year) teacher candidates enrolled in a Faculty of Education at a university. The sampling method used is purposeful sampling (Patton, 2002), which ensured the inclusion of volunteer participants from diverse departments—such as Primary School Education, English Language Teaching, and Mathematics Teaching. Restricting the study to the final year of the undergraduate program was based on the assumption that candidates at this stage would have clearer professional aspirations and more pronounced views on technology. Before data collection, participants were informed of the study's purpose, scope, and ethical processes (Creswell, 2013). Each participant was given an anonymous code (e.g., TC1, TC2, etc.), and it was emphasized that they had the option to withdraw from the study at any point.

Data Collection Tool

In this study, a Metaphor Generation Form was employed as the data collection tool to uncover teacher candidates' metaphorical perceptions of ChatGPT. The form was designed to allow participants both to complete a basic metaphorical statement, "ChatGPT is like … because …," and to justify their chosen metaphor. Additionally, several open-ended questions were included to gather teacher candidates' experiences and opinions concerning ChatGPT. Thus, beyond merely eliciting metaphorical expressions, the form also captured the feelings, thoughts, and attitudes underlying these metaphors. During the form's development, three main sections were established in line with the research topic and objectives:

Demographic Information

This section focuses on queries about the participants' department, academic year, gender, technology usage habits, and ChatGPT experience level. It was designed to investigate potential relationships between participants' metaphorical perceptions and their demographic characteristics.

Metaphor Generation

This core section asks participants to complete the statement, "ChatGPT is like … because …." Alongside producing the metaphor, participants are requested to briefly explain why they selected it. Questions such as "Why did you choose this metaphor?" and "Which emotions or thoughts led you to choose it?" aim to explore not just the metaphor itself, but also the thought processes influencing it.

Open-Ended Supporting Questions

Beyond metaphor generation, 2–3 additional open-ended questions invite teacher candidates' views on ChatGPT's potential in education, its associated risks, and its practical use in teaching. For instance, "Do you plan to use ChatGPT in your future teaching career? If so, how? If not, why?" or "Do you think ChatGPT could partially or entirely replace a teacher?" were included to prompt more comprehensive and personal assessments.

In developing the data collection tool, similar metaphor analysis studies in the literature were first reviewed (Saban, 2008; 2009; Yıldırım & Şimşek, 2018). Subsequently, input from four faculty experts was sought to ensure the items were intelligible and not leading. During a pilot phase, the form was administered to ten teacher candidates to test clarity, length, and conceptual adequacy. Based on their feedback, some items were simplified, and potentially leading statements were removed. The final Metaphor Generation Form was thus finalized as a set of ten questions.

Data Collection Procedures

Data were collected both online and face-to-face via the finalized Metaphor Generation Form. Candidates who met the sampling criteria were invited to participate on a voluntary basis. After obtaining ethical committee approval, participants underwent an informed consent procedure (Creswell, 2013). The data collection process occurred in two phases. In the first, a pilot group of approximately ten candidates completed the form to assess clarity, question length, and any potential bias (Yıldırım & Şimşek, 2018). Based on their feedback, the form was refined. In the second phase, the form was distributed to the main group of teacher candidates.

Face-to-face implementation involved handing out printed copies of the form during class sessions or scheduled intervals, giving participants around 15-20 minutes to respond. Online distribution utilized Google Forms or comparable platforms, with invitation links shared via email or social media groups (Patton, 2002). Participants were informed of their anonymity and privacy rights throughout; the form contained no sections that disclosed personal identifying information. Each submission was assigned a numerical code (TC1, TC2, etc.) for analysis, and candidates could withdraw at any point (Merriam & Tisdell, 2016).

Data Analysis

The data were analyzed using content analysis, a qualitative approach that systematizes, interprets, and synthesizes similar responses into meaningful categories and themes (Yıldırım & Şimşek, 2018). Written statements reflecting teacher candidates' metaphorical perceptions of ChatGPT underwent the following steps (Creswell, 2013; Merriam & Tisdell, 2016):

Data Organization and Raw Text Creation

All responses were digitized and assigned unique codes (TC1, TC2, …, TC220). Demographic details (department, gender, technology usage habits, etc.) were collated in a separate file, while the metaphors and explanations served as the principal data source for content analysis (Miles & Huberman, 1994).

Coding Process

Using an open coding approach, two researchers independently extracted key words, ideas, and analogies from the metaphors and their justifications (Yıldırım & Şimşek, 2018). Once coding was complete, they compared their results and determined the inter-coder reliability. By the Miles & Huberman (1994) formula, the agreement rate was computed at 88%. Discrepancies led to further discussion, re-reading participant statements, and—when necessary—consultation with a third researcher or advisor until consensus was achieved.

Theme Identification and Categorization

The initial codes were combined based on conceptual similarities, forming themes connected to the research objectives. For instance, participants' descriptions like "unlimited source of knowledge," "library," or "sea of information" were grouped under "Knowledge Repository." Regular meetings among the research team checked the clarity of themes and the scope of each category (Merriam & Tisdell, 2016). Achieving consistency among codes and themes facilitated a holistic understanding of the data.

Interpretation of Themes and Presentation of Findings

In the final stage, the identified themes and subthemes were arranged to comprehensively represent teacher candidates' metaphorical perceptions of ChatGPT. Descriptive analysis supported by direct quotations from participants reinforced the authenticity and trustworthiness of the findings (Creswell, 2013). The analysis also examined whether metaphors indicated positive, negative, or neutral perspectives, and relationships with demographic variables (department, gender, familiarity with technology, etc.) were explored. Tables and graphs were integrated when appropriate to enhance clarity.

Ethic

This study was conducted in strict adherence to ethical guidelines to ensure the protection and confidentiality of participants' rights, as well as to maintain transparency throughout the research process. Detailed information about the study's objectives, scope, methodology, and potential risks was provided to all participating teacher candidates, and informed consent was obtained from each participant. No identifying information was collected; instead, each participant was assigned a unique code to guarantee anonymity. The collected data were stored securely in environments accessible only to the research team, and individual responses were analyzed in aggregate to prevent identification. This study was carried out in accordance with the principles of autonomy, beneficence, and justice, ensuring the privacy of the participants and the overall academic integrity of the research

Findings

Metaphors Used for ChatGPT

The study's first research question investigated the metaphors teacher candidates employ to describe ChatGPT. Data from the Metaphor Generation Form revealed how participants positioned ChatGPT, highlighting the analogies they used to explain its role. Metaphors are powerful tools for illustrating the conceptual frames individuals use for understanding phenomena (Lakoff & Johnson, 1980). The analysis produced several overarching themes, summarized in Table 1, which shows frequently used metaphors, their repetition (frequency), percentage distribution, and direct quotations expressing participants' viewpoints.

Table 1. Teacher Candidates' Metaphors for ChatGPT, Frequencies and Exemplary Quotations

Theme	Metaphor Examples	Frequency (n)	Percentage (%)	Sample Quotation (TC Codes)
Knowledge Repository	Library, digital encyclopedia, boundless ocean of data	75	34.09	"ChatGPT is like a vast library because it instantly provides different kinds of information." (TC34)
Assistant / Guide	Mentor, advisor, consultant, helper	60	27.27	"When planning lessons, ChatGPT serves as a guide that lights my way." (TC89)
Black Box / Unfathomable Power	Black box, deep well, mysterious machine	40	18.18	"ChatGPT is like an uncontrollable black box; sometimes I see answers but have no clue where they really come from." (TC112)
Magic Wand / Miracle	Magic wand, miraculous fix, wizard assistant	30	13.64	"ChatGPT is like a magic wand, instantly clarifying complex topics in seconds." (TC58)
Other	Robot, mirror, joker card, bullet train, etc.	15	6.82	"ChatGPT is like a robot; it provides mechanical but effective responses as long as I give clear commands." (TC9)

As shown, Knowledge Repository (34.09%) is the most common theme, with participants perceiving ChatGPT as a broad reference source for diverse and immediate information. This suggests teacher candidates value the speed and variety of ChatGPT's data retrieval. Assistant / Guide (27.27%) indicates ChatGPT's perceived role as more than a mere informational tool; it also serves in developing lesson plans, generating questions, or providing unique teaching ideas. Notably, teacher candidates frequently invoke the words "mentor" and "guide," underscoring the potential of AI-based technologies in teaching and learning (Henrickson, 2023). In contrast, Black Box / Unfathomable Power (18.18%) highlights candidates' worries regarding the technology's opaque inner workings and data veracity—reflecting a degree of uncertainty and skepticism about how AI systems produce their responses (Bender et al., 2021). Magic Wand / Miracle (13.64%) demonstrates substantial enthusiasm or "awe" for ChatGPT's rapid and user-friendly capabilities. Yet this perspective sometimes coincides with unrealistic expectations that might lead to disillusionment if potential limitations are not acknowledged. Finally, the Other category (6.82%) covers a variety of metaphors (e.g., "robot," "joker card") suggesting teacher candidates' multifaceted impressions and experiences with ChatGPT.

Reasons Behind the Metaphors

The second research question probed the motivations and thematic frameworks shaping participants' chosen metaphors. In their descriptive comments, teacher candidates clarified how ChatGPT might benefit or pose challenges in educational contexts. Table 2 outlines these leading themes, their frequency, and direct quotations.

Table 2. Reasons for Metaphors and Thematic Justifications

Theme	Metaphor Examples	Frequency (n)	Percentage (%)	Sample Quotation (TC Codes)
Access to Information & Diversity	Speed, breadth, current data, navigation among different topics	70	31.82	"I think ChatGPT is like a library because I can find info on anything quickly." (TC51)

Time-Saving / Practical Utility	Streamlined lesson planning, question development, assignment checks	55	25.00	"ChatGPT, like an assistant, lightens my workload. It's especially helpful for new activity ideas." (TC102)
Reliability & Transparency Concerns	Accuracy of answers, unclear sources, potential bias	40	18.18	"I'm uneasy about not knowing how accurate it is; that's why I chose the black box metaphor." (TC88)
Tech Enthusiasm / High Expectations	Miraculous solutions, magic wand, groundbreaking innovation	30	13.64	"It can remove many challenges in teaching, so I call it a 'magic wand.'" (TC29)
Ethical Issues & Plagiarism	Student over-reliance, authenticity challenges, copyright uncertainty	15	6.82	"Students might use ChatGPT as a shortcut or cheat, which worries me. Conscious use is critical." (TC133)
Other	Robotic approach, irrelevant answers, limited experience	10	4.54	"It has no human aspect beyond commands, so it sometimes feels 'robotic.'" (TC12)
Total	-	220	100.00	-

Access to Information & Diversity (31.82%) emerges as the primary reason behind choosing certain metaphors, reflecting participants' high regard for ChatGPT's ability to rapidly deliver comprehensive knowledge. Time-Saving / Practical Utility (25.00%) underscores teacher candidates' recognition of ChatGPT as an efficient tool for course-related tasks. Conversely, Reliability & Transparency Concerns (18.18%) highlight anxiety about potential errors, unknown data sources, and AI algorithms' opacity (Bender et al., 2021). Tech Enthusiasm / High Expectations (13.64%) signals an optimistic outlook, though these sky-high expectations may lead to disappointment if not balanced by a realistic understanding of ChatGPT's limitations. Ethical Issues & Plagiarism (6.82%) touches on teacher candidates' fears that students might misuse ChatGPT, particularly regarding academic honesty and creative thinking. Lastly, Other (4.54%) indicates a smaller group perceiving ChatGPT as "mechanical" or "limited," emphasizing differences between AI-mediated and human-human interactions.

Positive, Negative, and Neutral Attitudes

Addressing the third research question, this segment explores the distribution of teacher candidates' metaphorical expressions according to positive, negative, and neutral attitudes toward ChatGPT. Table 3 shows the frequency and percentage of each category, along with quotations exemplifying such viewpoints.

Table 3. Distribution of Metaphorical Perceptions as Positive, Negative or Neutral

Attitude Category	Descriptors / Expressions	Frequency (n)	Percentage (%)	Sample Quotation (TC Codes)
Positive	Magic wand, knowledge storehouse, guide, assistant	110	50.00	"ChatGPT is basically a treasure trove of information; I save a lot of time looking for lesson materials." (TC47)
Negative	Black box, uncontrollable, unreliable, ethical worries	70	31.82	"I'm uneasy about false or source-unknown information, so I view it as a black box." (TC103)
Neutral	Balancing benefits and risks, conditional use, limited exposure	40	18.18	"I occasionally use ChatGPT; it's helpful but I'm not fully convinced, so I approach it cautiously." (TC19)
Total	-	220	100.00	-

Half of the participants hold positive perceptions, describing ChatGPT as a "guide," "treasure trove," or "assistant." About one-third convey negative views, underscoring "black box," "unknown," or "unreliable" aspects, often related to the system's opaque processes. The remaining neutral group frames ChatGPT as potentially beneficial yet advises caution due to perceived limitations. This distribution points to a broad range of attitudes among teacher candidates—some highly enthusiastic about the tool's advantages, others wary of ethical and transparency issues, and a moderate contingent seeking middle ground.

Influence of Demographic Variables:

Department and Familiarity with Technology

The fourth research question centers on how demographic factors—particularly academic department and familiarity with technology—affect metaphorical perceptions of ChatGPT. Table 4 summarizes the dominant metaphors and sample statements for each demographic subgroup.

Tablo 4. Distribution of Metaphorical Perceptions by Academic Major and Technology Familiarity

Demographic Variable	Dominant Metaphor Themes	Frequency (n)	Sample Quotation (TC Codes)
Department (Primary Ed.)	Knowledge Repository, Assistant/Guide	40	"ChatGPT helps me develop various class activities, acting like a guide." (TC28)
Department (English Ed.)	Knowledge Repository, Magic Wand/Miracle	35	"For translation and reading materials, ChatGPT is like a magic wand—fast and practical." (TC74)
Department (Math Ed.)	Assistant/Guide, Black Box/Unfathomable Power	30	"It's great for formulas and example problems, but I worry when I don't know where the answers come from." (TC119)
Department (Other Branches)	Knowledge Repository, Assistant/Guide, Black Box (mixed)	45	"ChatGPT is multipurpose, but I still cross-check with different sources." (TC175)
High Tech Familiarity	Magic Wand/Miracle, Assistant/Guide	40	"I've used digital tools for a long time, and ChatGPT really feels like a magic wand." (TC33)
Moderate Tech Familiarity	Knowledge Repository, Assistant/Guide	20	"I ask it basic questions, and it quickly provides summary info—quite handy." (TC52)
Low Tech Familiarity	Black Box/Unfathomable Power, Neutral/Uncertain Perspective	10	"I'm not very tech-savvy; ChatGPT sometimes gives confusing answers, so I don't fully trust it." (TC201)
Total	-	220	-

Primary Education majors favor "Knowledge Repository" and "Assistant/Guide," while English Education majors add "Magic Wand/Miracle" to "Knowledge Repository," suggesting a more optimistic stance. Mathematics Education students emphasize "Assistant/Guide" yet also note "Black Box/Unfathomable Power," indicating caution over ChatGPT's reliability. In "Other Branches," a more blended approach emerges, although "Knowledge Repository" and "Assistant/Guide" remain prevalent. Examining technology familiarity reveals that teacher candidates with high familiarity tend toward "Magic Wand/Miracle" metaphors. Those with a moderate level mainly adopt "Knowledge Repository" or "Assistant/Guide," and those with low familiarity often reference "Black Box/Unfathomable Power" or hold generally neutral views, mentioning limited understanding of how ChatGPT functions or doubting the credibility of its outputs. Altogether, these findings affirm that departmental context and technological proficiency shape teacher candidates' metaphorical perceptions of ChatGPT in meaningful ways.

Conclusion and Discussion

This study investigated teacher candidates' metaphorical perceptions of ChatGPT, shedding light on how AI-based language models are currently perceived and potentially integrated in the educational sector. The findings indicate that while candidates predominantly embrace ChatGPT as a "Knowledge Repository" or "Assistant/Guide," they also harbor considerable reservations, captured by metaphors like "Black Box/Unfathomable Power." Thus, although teacher candidates demonstrate robust interest and curiosity, they face lingering doubts about credibility and correctness.

Positive metaphors largely emphasize "fast information access," "time savings," and "ease in lesson planning." Yet negative or cautious outlooks highlight "ethical concerns," "lack of transparency," and "unclear data sources." These dual attitudes underscore that merely offering advanced technological tools is insufficient; the process must also address pedagogical and ethical frameworks. Particularly noteworthy is how teacher candidates who portrayed ChatGPT as a "magic wand" appear to expect transformative outcomes in teaching. However, such high expectations might, if poorly managed, lead to disappointment (Davis, 1989).

Overall, the research demonstrates that teacher candidates interpret ChatGPT in diverse ways and that their attitudes hinge on academic major and technological literacy. These findings underscore the need to strengthen AI literacy in teacher education programs, ensuring that prospective educators gain both technical competency and ethical awareness. Hence, fostering the informed, critical, and responsible use of AI-based technologies becomes a strategic target for teacher education and educational technology policies.

Metaphorical Diversity and Teacher Candidates' Readiness for Technology

Research findings indicate a notable diversity in the metaphors teacher candidates use to describe ChatGPT. This diversity stems not only from candidates' personal experiences and disciplinary requirements but also from their varying degrees of technological readiness and motivation (Lu, Liu, & Wang, 2023). In particular, the themes of "knowledge repository" and "assistant" reflect a need for rapid and multifaceted access to information through ChatGPT (Holstein, Aleven, & Rummel, 2023). Conversely, the presence of metaphors such as "black box" suggests that concerns about using this technology have yet to be fully alleviated (Bender et al., 2021).

Hence, teacher candidates' preparedness for technology extends beyond purely technical abilities. Rather, they also require critical thinking, ethical awareness, and pedagogical adaptation skills regarding AI tools like ChatGPT (Kim & Lee, 2023). The absence of coursework on AI and big data in teacher education programs may lead candidates toward indecision or excessive optimism when selecting their metaphors. Consequently, "metaphorical diversity" may simultaneously mask candidates' gaps in experience and knowledge. In this sense, understanding the perceptions behind these metaphors can provide valuable guidance for designing more comprehensive and up-to-date teacher education curricula (Russell & Norvig, 2010).

Rationales Behind Metaphors: Trust and Ethical Concerns Versus Speed and Variety

Data collected in this study indicate that teacher candidates cite factors such as "time-saving," "swift access to information," and "the provision of diverse content" as positive justifications for using ChatGPT. This finding suggests that practicality and functionality figure prominently among teacher candidates' expectations of technological tools in the teaching-learning process (Chang & Fang, 2023). For instance, the idea of quickly retrieving sample questions or materials during lesson planning significantly boosts candidates' interest in ChatGPT (Wang & Huang, 2021). In this regard, Davis's (1989) concept of "perceived usefulness" appears to exert a strong influence.

On the other hand, negative or cautious rationales focusing on "reliability" and "ethical issues" reveal that candidates adopt a critical stance toward this technology (Luckin, 2018). The possibility that ChatGPT might generate incorrect or conflicting information, omit proper source attribution, or leave unclear the origin of its responses contributes to its perception as a "black box" or "unfathomable power" (Bender et al., 2021). Furthermore, concerns around plagiarism, loss of originality, and copyright infringement prompt teacher candidates to approach ChatGPT with caution in classroom settings (Miao et al., 2023). Consequently, it may be argued that teacher education programs should explicitly address AI literacy, fact-checking, and ethical standards (Kim & Lee, 2023).

Distribution of Positive, Negative, and Neutral Attitudes: A Dual Perspective on AI

Half of the participants display positive attitudes toward ChatGPT, one-third adopt negative attitudes, and the remaining participants remain neutral. This distribution points to a multifaceted adoption process of AI tools in education (Mueller & Strohm, 2022). On the one hand, it reflects the excitement surrounding the high potential of AI technologies; on the other hand, it reveals uncertainty tied to unresolved ethical and technical issues (Ai & Chen, 2023). Consequently, while the majority view ChatGPT as a tool offering practical benefits to the teaching profession, a considerable segment remains cautious due to perceived risks and ambiguities.

This finding underscores that the digital transformation of education is not merely a matter of infrastructure or technological resources; it also involves teacher candidates' beliefs, attitudes, and value systems (Miao et al., 2023). Similarly, Selwyn (2019) discusses the societal and ethical dimensions of

AI in education as integral to whether these technologies are adopted or rejected. It follows that teacher candidates who maintain neutral positions might be guided toward a more constructive stance on AI through appropriate educational policies and awareness-raising initiatives (Henrickson, 2023).

Effect of Demographic Differences: Academic Major and Technological Familiarity

Differences in academic major and technological familiarity have emerged as significant variables influencing perceptions of ChatGPT. For instance, candidates in English or Primary Teacher Education programs are more inclined to adopt "knowledge repository" and "magic wand" themes, whereas Mathematics teacher candidates frequently employ the "black box" metaphor, expressing skepticism regarding reliability (He & Chen, 2023). These divergences may stem from the specific pedagogical and curricular needs of each discipline, as well as the technology culture within each faculty (Koehler & Mishra, 2009).

Additionally, teacher candidates possessing high technological proficiency tend to extol ChatGPT with stronger metaphors such as "magic wand," whereas those with limited technological experience exhibit greater caution and concern (Zhai, 2022). This observation underscores that the success of AI integration largely depends on teacher candidates' technological competencies and digital literacy levels (Chang & Fang, 2023). Accordingly, universities and policy makers should implement multifaceted instructional designs tailored to distinct majors and varying degrees of prior experience (Kim & Lee, 2023). With carefully crafted strategies for each field and competency level, prospective teachers can learn to use ChatGPT and similar tools both responsibly and effectively.

Suggestions

1. This study utilized metaphor analysis. Future research could employ mixed-method designs that integrate quantitative approaches (e.g., technology acceptance models, AI attitude surveys) with qualitative methods to provide a more comprehensive understanding.
2. Experimental studies with teacher candidates from different disciplines could be conducted to concretely measure the impact of ChatGPT on lesson planning, instructional material development, and assessment processes.
3. Comparative studies examining teacher candidates' metaphorical perceptions of ChatGPT across various universities, regions, and countries would help elucidate how cultural and institutional factors shape attitudes toward technology.
4. Given the clear concerns regarding ethics and reliability among teacher candidates, further research should systematically explore strategies to mitigate risks associated with AI tools, such as misuse (e.g., plagiarism, issues of originality) and the propagation of bias.

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Prospective Elementary Mathematics Teachers' Views on the Use of Islamic Geometric Patterns in Mathematics Lessons

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Abstract

This study aims to examine the views of prospective elementary mathematics teachers regarding the use of Islamic Geometric Patterns (IGPs) in mathematics lessons. Conducted within a qualitative research design, the study collected data from seven teacher candidates—third-year students who had taken an elective course on IGPs—through a semi-structured interview form. The data were analyzed using content analysis, and a descriptive approach was adopted to interpret the findings based on themes, categories, and codes. The analysis revealed that the experiences and opinions of the teacher candidates about the use of IGPs were grouped under seven main themes: "Interest and Attitude Towards Mathematics," "Establishing Interdisciplinary Context," "Creativity and Instructional Design Skills," "Visualization and the Concretization of Geometric Concepts," "Integrating Historical and Cultural Context into Teaching," "Limitations and Challenges," and "Suggestions for Effective Utilization." The findings indicate that IGPs can contribute to developing positive attitudes toward mathematics, fostering interdisciplinary integration, supporting creativity and instructional design skills, facilitating the understanding of geometric concepts, and providing a cultural-historical perspective. However, issues such as time management, topic alignment, and material shortages may prevent smooth implementation in every context. The study highlights that IGPs can serve as a potential tool for enriching mathematics teaching, enhancing students' motivation and comprehension levels, and encourages the development of guiding resources, technological support, collaborative activities, and practical applications to realize this potential.

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Introduction

One of the main objectives of mathematics education is to enable students to make sense of abstract concepts, develop geometric thinking skills, and cultivate a positive attitude toward mathematics (Ward, 2003; Rumanová & Smiešková, 2015). In this regard, instead of merely transmitting theoretical information, a learning-teaching process enriched with cultural, artistic, and historical elements can provide students with a meaningful mathematical experience (Verner, Massarwe & Bshouty, 2013; Zuliana, Dwiningrum, Wijaya & Purnomo, 2023). Particularly in the field of geometry, the importance of aesthetic and cultural motifs for creating real-life connections, establishing interdisciplinary contexts, and strengthening visual-spatial thinking skills is becoming increasingly evident (Chang, 2018; Hemmerling, 2019; Karadağ & Akar, 2020).

Ornamentation refers to covering surfaces or structures with one or more geometric shapes, without gaps or overlaps (Aktaş, Ercan & Bulut, 2024; Britton & Seymor, 1989, as cited in Aktaş et al., 2015). Throughout history, ornamentation has found correspondences in various fields such as architecture (Takva & Takva, 2023; Takva, Takva & Takva, 2023), engineering (Kizilörenli & Maden, 2021), art (Webb, 2019), ethnomathematics (Verner et al., 2019; Zuliana et al., 2023), education (Aydin-Güç & Hacisalihoglu-Karadeniz, 2020; Ovadiya, 2019), technology (Laksmiwati et al., 2023), and handicrafts (Karadağ & Akar, 2020; İpek & Özmüş, 2014). In Islamic architecture, Islamic Geometric Patterns (IGPs)—which appear on pulpits (minbar), prayer niches (mihrab), columns, and wall coverings with regular or semi-regular patterns—stand out for their use of polygons such as squares, hexagons, and octagons, formed through various applications of transformational geometry (reflection, translation, rotation) (Aktaş et al., 2015; Eryılmaz & Selimgil, 2021).

These Patterns in Islamic architecture are essentially concrete manifestations of mathematical principles in space (Takva & Takva, 2023; Bush, 2021; Eryılmaz & Selimgil, 2021). In examples such as Beyşehir Eşrefoğlu Mosque, Sivrihisar Ulu Mosque, and Konya Alâeddin Mosque in Turkey, the patterns on pulpits and mihrabs demonstrate the effectiveness of geometry in architectural production and reveal how mathematical relations intertwine with cultural-historical contexts (Takva & Takva, 2023). Similarly, patterns produced using various materials, such as stone, wood, and tiles in places like Iran, Morocco, India, Spain, Egypt, and Uzbekistan, reflect the mathematical heritage of Islamic culture (Eryılmaz & Selimgil, 2021; Kılıçoğlu & Pilehvarian, 2017).

In educational contexts, such Patterns offer opportunities for students to recognize polygons, discover types of symmetry, and make sense of the concepts of transformation geometry (reflection, rotation, translation) (Ward, 2003; Callingham, 2004). Through this process, students associate abstract concepts with cultural heritage and aesthetic elements, thus experiencing a more meaningful learning environment (Rumanová & Smiešková, 2015; Verner et al., 2013; Webb, 2019). The literature shows that this approach increases student motivation (Laksmiwati et al., 2023), supports creative problem-solving skills (Ilucová, 2004; Ovadiya, 2019), encourages the meaningful use of technology (Ward, 2003; Laksmiwati et al., 2023), and offers an ethnomathematical perspective (Zuliana et al., 2023; Verner et al., 2019).

For prospective teachers, this approach has the potential to enhance professional competencies, innovative material development skills, and cultural sensitivity (Capone et al., 2024; Hemmerling, 2019). In line with the ethnomathematical approach, prospective teachers can bring activities into the classroom that make mathematics meaningful by considering students' cultural experiences (Verner et al., 2013; Verner et al., 2019). Thus, mathematics education provides a richer learning experience at the intersection of cultural heritage, art, architecture, and technology (Karadağ & Akar, 2020; İpek & Özmüş, 2014).

Ornament-based activities not only enable students to understand concepts such as transformation geometry, symmetry, proportion, and pattern but also create opportunities to develop manual skills, use technological tools, foster collaborative learning, and build cultural awareness (Chang, 2018; Aktaş, Ercan & Bulut, 2024; Yamamoto, Nakazato & Mitani, 2022). Examples such as Anatolian ornamentations and

Islamic geometric designs help students relate mathematical content to cultural elements they might encounter in daily life (İpek & Özmüş, 2014; Eryılmaz & Selimgil, 2021; Bush, 2021).

At this point, although studies on using ornamentation in education are increasing in the literature (Tekin, 2024), there is a need for systematic research examining the views of prospective teachers specifically in the context of Islamic Geometric Patterns. Further research is required on how IGPs can be used in elementary mathematics lessons, and their effects on students' attitudes, conceptual understanding levels, and cultural awareness (Karadağ & Akar, 2020; Verner et al., 2019; Zuliana et al., 2023).

This study aims to fill this gap in mathematics education literature by determining prospective teachers' experiences, attitudes, and perceptions regarding the use of IGPs in mathematics lessons. The findings may guide teacher training programs, material development processes, curriculum design, the effective use of technology, and the adaptation of ethnomathematics-based activities to the classroom context. Thus, it is expected to contribute to adopting a holistic teaching approach that highlights the cultural, aesthetic, and interdisciplinary dimensions of mathematics education.

The main purpose of this research is to reveal the experiences, attitudes, and perceptions of prospective teachers regarding the use of IGPs in elementary mathematics teaching. In this way, the potential contributions of ornament-based activities to student motivation, conceptual understanding, relating cultural heritage, creative thinking, and developing interdisciplinary contexts will be evaluated. The results are expected to emphasize the importance of teaching approaches that consider the cultural, aesthetic, and creative dimensions of mathematics education and enrich the literature.

Method

This study is a basic qualitative inquiry conducted within a qualitative research framework (Creswell, 2013; Merriam & Tisdell, 2015). The data were thematically structured through content analysis, enabling an in-depth examination of participants' subjective perceptions, experiences, and thoughts (Braun & Clarke, 2006; Miles, Huberman & Saldaña, 2014).

Participants

The participants of the study consist of seven prospective teachers in their third year of a university's elementary mathematics teacher education program who voluntarily chose an elective course on IGPs. These participants, who formed the primary data source of the research, reflected on their experiences gained during the IGO course.

Data Collection Tool and Procedure

Data were collected through a semi-structured interview form. This form contained open-ended questions focused on the integration of IGPs into mathematics lessons, their possible contributions to mathematical thinking skills, teaching materials, the establishment of interdisciplinary contexts, lesson planning experiences, and suggestions for practice. Participants provided written responses, allowing them to express their experiences in detail. Anonymity and confidentiality were carefully observed.

Data Analysis

The collected data were analyzed through content analysis. First, the data were read holistically, and then meaningful expressions were coded. Similar codes were merged to form sub-categories, categories, and themes (Braun & Clarke, 2006). Multiple researchers independently coded the data to ensure reliability, and discrepancies were discussed until a consensus was reached. The themes allowed a comprehensive and systematic presentation of the findings.

Findings

As a result of the content analysis, the views of prospective teachers on the use of Islamic Geometric Patterns (IGPs) in mathematics lessons were gathered under seven main themes. These themes are the product of a holistic understanding of the data and reflect participants' perceptions and experiences across a broad spectrum, from attitudes toward the lesson to interdisciplinary connections, from creativity and instructional design skills to the concretization of geometric concepts, historical-cultural dimensions, challenges encountered in practice, and suggestions for more effective use. Below, we first present the related categories and codes under each theme, followed by a detailed discussion of how these themes materialized through participant statements, thereby providing the reader with a detailed, systematic, and comprehensive account of the findings.

Theme 1: Interest and Attitude Towards Mathematics

Two key categories stand out in this theme: (1) Making Mathematics Enjoyable and (2) Increased Motivation. These categories are substantiated by codes such as “developing a positive attitude,” “increased interest in the lesson,” “arousing curiosity,” and “fun learning environment.”

Participants’ statements indicate that IGPs can make abstract mathematical concepts more appealing, leading students to adopt a more positive attitude toward the lesson. For instance, one participant stated, “...this can prevent students’ negative attitudes toward mathematics” (P1), emphasizing that IGO-based activities could break preconceptions. Another participant mentioned, “Islamic geometric Patterns made the topic more interesting” (P4), pointing out that IGPs transform mathematics lessons into environments that grab and pique students’ curiosity. Similarly, “Experiencing mathematics in a concrete context can strengthen positive attitudes” (P2) underscores that presenting mathematics—often filled with abstract concepts—in concrete examples can bolster students’ motivation. Another participant added, “It becomes easier to capture the attention of that age group, and it can be shown that math is not a subject to be feared” (P7), highlighting how IGPs can foster positive emotions toward mathematics.

Theme 2: Establishing Interdisciplinary Context

Two categories emerged here: (1) Integration with Other Courses and (2) Multi-Dimensional Learning Experience. Under these categories, codes such as “connecting with religious education and ethics,” “integration with social studies,” “integration with visual arts,” and “relating to real life” show that mathematics can merge with various disciplines, creating meaningful learning opportunities.

One participant said, “A learning experience that blends religious culture and ethics, social studies, and visual arts can be offered” (P1), noting that IGPs provide a means to move mathematics beyond just numbers and operations, allowing for a broader contextual examination. Another participant remarked, “Teaching the history of a mosque in social studies and its ornamentation in mathematics makes a lot of sense” (P5), emphasizing that mathematics offers an analytic framework for students to interpret culturally and historically shaped spaces. Other comments included, “This demonstrates that mathematics is not just about numbers but is connected to all subjects” (P7) and “Establishing interdisciplinary connections also contributes to students’ multi-faceted thinking” (P3). These views indicate how IGPs help students discover different modes of thought and regard mathematics as a discipline situated in everyday life, art, history, and culture.

Theme 3: Creativity and Instructional Design Skills

In this theme, categories such as Activity Development and Material Design and Creativity and Patience Development stand out, with relevant codes including “lesson plan preparation,” “variety of activities,” “manual skills,” and “a process requiring patience.” The statements of teacher candidates suggest that IGPs enrich instructional design processes and encourage creativity.

For example, one participant noted, “I realized I had to pay attention to every detail when preparing the lesson plan” (P1), implying that IGPs require a more meticulous approach to lesson design. “I think I can develop various activities” (P2) indicates that IGPs inspire prospective teachers to create innovative learning experiences. Moreover, “Drawing and coloring enhanced my creativity” (P4) points out how activities requiring aesthetic and manual skills can also stimulate creativity alongside professional skills. Another participant added, “It was a course that required patience and should be voluntary” (P7), emphasizing that this process further cultivated the patience and dedication of teacher candidates. Thus, IGPs serve as a laboratory that strengthens prospective teachers' pedagogical and artistic abilities.

Theme 4: Visualization and the Concretization of Geometric Concepts

Two categories emerge here: Recognition and Classification of Geometric Shapes and Patterns and Symmetry. Codes such as "polygons," "classification by the number of edges," "repetitive patterns," and "translation and reflection" highlight how IGPs reinforce geometry topics with concrete examples.

Participants stated, "It can be used in teaching polygons; they can be classified by the number of sides" (P3), emphasizing how IGPs make abstract geometric concepts more tangible. Another participant mentioned, "In discussing patterns, one can question at what intervals certain shapes repeat" (P4), drawing attention to the mathematical structure of designs. "Teaching symmetry through designs could make it easier for students to understand" (P6) argues that visual arrangements leave more lasting impressions on students' minds. Additionally, "Presenting abstract mathematical concepts in a visual and concrete manner strengthens problem-solving skills" (P2) and "Classifying geometric shapes based on coloring or drawing provides more meaningful and lasting learning" (P1) illustrate how IGPs support students' problem-solving and analytical skills through visual methods.

Theme 5: Integrating Historical and Cultural Context into Teaching

Cultural Awareness and the Universal Nature of Mathematics stand out as categories under this theme. Codes such as "historical sites" and "connection with cultural heritage" suggest that mathematics is not merely an abstract discipline but one that holds a specific historical and cultural background.

Teacher candidates note, "Now I examine Patterns I see; I look at my surroundings with different eyes" (P7), indicating that IGPs allow students to read the geometric patterns they encounter in daily life through a cultural-historical lens. Another participant stated, "It showed that mathematics can be integrated into any field" (P2), pointing to the universality of mathematics. Also, "It's very logical to teach the mosque or tomb in religious education, its history in social studies, and its structure in mathematics" (P5) suggests that this historical and cultural context can transform lessons from isolated segments into an interdisciplinary and holistic learning experience.

Theme 6: Limitations and Challenges

The categories of Time Management Issues and Limited Integration Opportunities indicate that implementing IGPs is not always seamless, as reflected by codes such as "time-consuming" and "limited applicability to certain topics."

One participant admitted, "It took a lot of time and was challenging" (P7), implying that planning IGO activities demands meticulous work. "Time constraints can arise, so practice is needed" (P3) similarly stresses the need for effective time management. Some participants noted, "I think the scope of the lesson is not that broad; the mathematical theme that can be integrated is limited" (P1), suggesting that not all topics are suitable for IGPs. "I think it can be tackled for just one theme at most" (P5) also points to a narrowing scope. Additionally, "Procuring materials was initially challenging" (P4) highlights how material shortages could negatively impact the process.

Theme 7: Suggestions for Effective Utilization

This final theme focuses on Resource and Material Support and Hands-On and Collaborative Learning, presenting codes such as "creating a guidebook," "use of technology," "collaborative learning," and "real-life connections."

Participants noted, "Publishing books or magazines tailored to this area would clarify teachers' paths" (P1), emphasizing the importance of reference materials. "Students can develop their creativity by creating their own designs" (P2) points to the necessity of practical, student-centered activities, while "Making puzzle-like cutouts or increasing hands-on activities could be more fun, meaningful, and effective" (P6) highlights the potential for more engaging practices. In addition, "Active use of technological tools and connecting lessons to real life is important" (P2) underlines how IGPs can be integrated with contemporary educational technologies and supported with examples closely related to students' lives.

Conclusion And Discussion

This study examined the views of prospective teachers on the use of IGPs in mathematics lessons, revealing that Patterns can contribute to a broad range of outcomes, from understanding mathematical concepts to developing cultural awareness. In line with the literature, the findings show that Patterns can enhance students' attitudes toward mathematics (Ward, 2003; Webb, 2019), facilitate the concretization of abstract topics like transformational geometry, symmetry, and polygon properties (Callingham, 2004; Rumanová & Smiešková, 2015), and offer opportunities for interdisciplinary learning (Verner et al., 2013; Zuliana et al., 2023; Karadağ & Akar, 2020).

Prospective teachers' emphasis on how IGPs can increase student motivation, foster aesthetic sensibility, and bolster creativity and material development skills aligns with existing findings about the educational potential of ornamentation (Hemmerling, 2019; Ovadiya, 2019). Moreover, it is understood that using technological tools in ornament-based activities can offer an exploratory learning environment (Chang, 2018; Laksmiwati et al., 2023; Yamamoto et al., 2022), integrating a cultural perspective into mathematics learning through an ethnomathematical approach (Verner et al., 2019; Zuliana et al., 2023).

However, the research findings also show that challenges such as time management, topic alignment, and material shortages can hinder the use of Patterns in practice. Similar limitations are highlighted in the literature, suggesting that prospective teachers overcome these barriers by utilizing guide materials, professional development programs, technology-supported activities, and collaborative study methods (Capone et al., 2024; Tekin, 2024).

Limitations And Recommendations

This study was conducted with a limited number of prospective teachers. Future research involving more diverse participants from different cultural and academic backgrounds could enhance the generalizability of the findings. Additionally, rather than focusing solely on prospective teachers' views, classroom observations, analyses of student work, and long-term impact assessments could be employed to gain a more comprehensive understanding of how ornament-based activities influence the teaching process.

In subsequent studies, the use of software such as GeoGebra and TbMT in ornament activities could be explored, supporting prospective teachers' technological literacy, creative material development, and student-centered approaches to discovering geometric concepts. By incorporating courses on planning and implementing ornament-based activities into teacher training programs, both the mathematical and cultural capital of prospective teachers could be enriched. Investigating ornamentations from various cultural heritages could also help students appreciate that mathematics is a universal language.

In summary, this study emphasizes the value that IGPs can add to mathematics education in terms of aesthetics, culture, and interdisciplinarity. By adopting this approach, prospective teachers can contribute to students experiencing mathematics as a more meaningful, engaging, culturally enriched, and creative field of activity. In this regard, the diversification of ornament-based activities, their integration with technology, incorporation into teacher training programs, and long-term impact assessments will provide opportunities to enrich mathematics education with an innovative and holistic perspective.

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Identifying the difficulties in developing hypothesis formation skills in science classes

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Abstract

One of the key components of scientific literacy is scientific process skills. Among scientific process skills, the ability to formulate hypotheses can be considered a higher-order skill. Therefore, it is of great importance to develop and foster this skill in science classrooms. This is because experimental and observational activities, which are inherent to the nature of science, frequently require this skill. The aim of this study is to identify the current state of sixth-grade students' hypothesis-forming skills and to determine the challenges they face in developing this skill. The participant group of the study consists of 42 students attending a middle school located in the city center of Nevşehir. The study was conducted using an exploratory mixed-methods research design. A mixed-methods design is one that involves the collection and integration of both qualitative and quantitative data. In this context, to obtain detailed and comprehensive data considering the challenges in developing hypothesis-forming skills, the quantitative phase of the study included the administration of the Scientific Process Skills Test, the Science Anxiety Scale, and the Science Learning Motivation Scale to the participants. In the qualitative phase of the study, semi-structured interviews were conducted with eight students selected according to predetermined criteria. In addition, data triangulation was sought through 16 weeks of classroom observations. According to the findings obtained from the analysis of quantitative and qualitative data, the average score students received on hypothesis-forming questions was moderate (M = 2.85) on a six-point scale. The minimum and maximum scores obtained from the hypothesis-forming questions were 2 and 5, respectively. It was observed that students had difficulty identifying the factors to be controlled and the variables to be manipulated in experimental setups. This difficulty in identifying variables was also reflected in their ability to formulate hypotheses. This is because a hypothesis is generally constructed using variables. Furthermore, it can be said that students had difficulty in reading comprehension in the hypothesis-related questions, and thus were unable to establish a meaningful connection between the scenario presented in the question stem and the listed options.

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Introduction

One of the most important and widespread goals of education is to teach thinking. The primary mission of schools at all levels and the science courses offered within them is to fulfill this objective. Due to advancements in science and technology and the resulting increase in global competition, unresolved global problems at the core of the sciences highlight the importance of science education for the future (McFarlane, 2013). One of the fundamental aims of science education is to help students understand the core ideas in science as well as the significance and impact of science on society (Liu, 2009).

Science education aims not only to transmit knowledge, but also to foster students' cognitive and affective development, equipping them with the skills necessary to cope with real-life problems. In order to cultivate individuals with such competencies, the importance of integrating experimental and observational data with abstract conceptual relationships is becoming increasingly prominent, especially in the field of science education. The primary objective of science curricula in Turkey has been defined as raising scientifically literate individuals (MoNE, 2005, 2018). Scientific literacy is a combination of science-related skills, attitudes, values, understandings, and knowledge that are essential for individuals to develop research and inquiry abilities, think critically, solve problems, make informed decisions, become lifelong learners, and sustain their curiosity about the world and their environment.

Globally, science curricula and course content are continuously updated to equip students with these essential competencies. In Turkey as well, the 2005 Science and Technology curriculum and all subsequent programs have emphasized that every student should be educated as a scientifically literate individual, regardless of their individual differences.

Scientific process skills, as one of the dimensions of scientific literacy, are regarded as a key means of fostering thinking strategies in science education (Kol & Yaman, 2022; Padilla, 1984). Scientific process skills are sets of abilities that encompass scientists' capacity to make sense of nature and their cognitive processes (Taşkın & Koray, 2006). These skills can be considered a form of scientific thinking and support qualities such as inquiry, creation, and scientific communication. Individuals with well-developed scientific process skills are more likely to adapt to technological advancements and the resulting international competition that emerges on a global scale (Gündoğdu, 2011). In order for individuals to contribute to the advancement of science and technology, they must be educated to think like scientists and possess scientific process skills. Scientific process skills can be briefly defined as the skills that scientists use in the course of conducting their work. Although there are various classifications in the relevant literature, it is generally accepted that there are thirteen scientific process skills: eight of them—such as observation, classification, and measurement—are considered basic-level, while five—such as hypothesis formation, variable identification, and experimental design—are regarded as higher-level skills (Akdeniz, 2011).

Scientific process skills (SPS) are not only a tool for understanding science learning and scientific inquiry, but also constitute an important goal of education (Anagün & Yaşar, 2009). In lifelong learning processes, individuals are required to learn, analyze, and evaluate events they encounter under different conditions; therefore, scientific process skills are of great importance for meaningful learning (Bilgin, 2006). In inquiry-based learning environments, activities carried out by individuals through active learning approaches require not only the development of feasible hypotheses for the identified problem, but also emphasize the critical importance of the variable identification stage, where the rationale behind the planned activities is questioned.

The ability to formulate hypotheses plays a key role in the development of multiple scientific process skills, especially the skill of identifying and controlling variables (ICV). This is because the skill of hypothesis formulation, which is defined as the generation of claims or proposed explanations for natural phenomena or events occurring in the universe, necessitates the use of ICV skills (Hughes & Wade, 1993). When constructing a hypothesis, it is important to focus not on the truthfulness of the explanation, but rather on formulating a proposition based on variables that reflect the cause-and-effect relationship—namely, dependent, independent, and controlled variables. In a sample research process conducted with students in a science course, if hypothesis formation is carried out in this structured way, the experimental setup required to test the hypothesis can be constructed more easily. As can be inferred from this, both hypothesis formulation (HF) and ICV skills can be said to contribute to the development of experimental design skills (Bayraktar et al., 2006). Due to the contributions of hypothesis formulation to effective science instruction, this study focuses on the challenges faced by middle school students in developing this skill.

In Turkey, most studies focusing on SPS have been conducted using quantitative research approaches, and they have primarily aimed to reveal the relationships between SPS and variables such as students' academic achievement, attitudes toward the course, and motivation (Aktaş, 2016; Aktaş & Ceylan, 2016; Aydoğdu, 2006; Bilgin, 2006; Doğan, 2018; Duru et al., 2011; Karar & Yenice, 2012; Meriç & Karatay, 2014). However, there is a lack of studies that identify and improve SPS in science classes through qualitative research approaches, which allow for more detailed and comprehensive data collection. Yet, considering the complexity of the cognitive and affective processes involved, it is essential from a literature perspective to examine these skills in greater detail and with a more focused lens. Therefore, this study aims to explore the possible reasons why the skill of hypothesis formulation has not been adequately developed in science classes, by focusing specifically on this skill. Accordingly, the research questions (RQs) of the study have been formulated as follows:

RQ1. What is the current state of sixth-grade students' HF skills?

RQ2. What difficulties do sixth-grade students face regarding their HF skills?

Method

Johnson and Onwuegbuzie (2004) emphasized that mixed methods research has two primary purposes: The first is to ensure variation and complementarity within the data set; The second is to generate new research questions by utilizing findings through the processes of initiation, development, and expansion. Therefore, mixed methods research becomes necessary when a researcher seeks to answer not only the "what" of a study, but also the "how" and "why," in order to uncover different dimensions of the phenomenon being investigated. Due to the aforementioned advantages of mixed methods research, the explanatory sequential design was employed in this study. As is well known, a mixed design involves the collection of both qualitative and quantitative data, integrating both methods within a single study (Fraenkel et al., 2012; Gay et al., 2012). The aim of this design is to achieve a more detailed and comprehensive understanding of a phenomenon by leveraging the strengths of both qualitative and quantitative methods (Mills & Gay, 2016). The explanatory sequential design, on the other hand, involves the researcher first conducting a quantitative study and analyzing the results, then restructuring these findings in greater depth through qualitative research (Creswell, 2017).

In this study, which centers on scientific process skills—one of the key dimensions of scientific literacy—quantitative data were collected first. Qualitative data, on the other hand, were collected through classroom observations and semi-structured interviews. Taking into account the challenges in developing "hypothesis formulation" and "identifying/controlling variables" skills, the quantitative phase of the study aimed to obtain detailed and comprehensive data by administering the Scientific Process Skills Test (SPST), the Science Course Anxiety Scale (SCAS), and the Science Learning Motivation Scale (SLMS) to the participants (N=42).

Participants

The participants of the study consisted of sixth-grade students attending a middle school located in the city center of Nevşehir. Although the study group initially consisted of 45 students, this number dropped to 42 during the process due to various reasons such as transferring to another school, experiencing learning difficulties, or being unable to complete the scales. Since one of the researchers was the science teacher of these students, it was easier to access the in-depth and comprehensive data structures inherent in qualitative research designs. The school where the study was conducted was selected using the convenience sampling method. The convenience sampling method involves selecting participants from easily accessible and practical groups due to limitations in time, cost, and labor (Büyüköztürk et al., 2021). In order to collect the quantitative data, the designated scales were administered to 42 students (20 girls and 22 boys). Information about the 8 students who participated in the semi-structured interviews is presented in Table 1. In selecting the students for the interviews, gender, scientific process skills test scores, and the results from other data collection instruments were taken into account. Thus, an effort was made to obtain the most detailed and comprehensive data in line with the purpose of the study.

Table 1. Descriptive information of the interviewed participants

Participant	Age	Gender	Course Level	SPS Mean	Motivation Mean	Anxiety Mean
P1	11	Female	6/B	19	89	45
P2	11	Male	6/A	18	87	47
P3	11	Female	6/B	14	79	50
P4	12	Male	6/A	10	72	54
P5	11	Male	6/A	11	75	59
P6	12	Female	6/A	18	89	49
P7	12	Female	6/B	9	70	63
P8	11	Male	6/B	20	90	46

Data Collection Tools

Scientific Process Skills Test (SPST)

The SPST was originally developed by James R. Okey and his colleagues. Its translation and adaptation into Turkish were conducted by Özkan et al. (1996) (Yavuz, 1998). In this study, the SPST consisting of 25 multiple-choice questions revised by Aydoğdu (2006) was used. The test includes three questions (items 1, 4, and 17) targeting the "measurement" skill, and fourteen questions (items 2, 5, 8, 9, 10, 12, 13, 14, 15, 16, 21, 22, 23, and 25) addressing the skill of "identifying and controlling variables," six questions (Items 3, 7, 11, 18, 20, and 24) targeting the "hypothesis formulation" skill, and two questions (Items 6 and 19) aimed at assessing the skill of "interpreting data. The reliability coefficient of the test was calculated as 0.81.

Science Course Anxiety Scale (SCAS)

Within the scope of this study, the 5-point Likert-type "SCAS," developed by Kağıtçı (2014), was used to determine students' anxiety levels toward the science course (Kağıtçı & Kurbanoğlu, 2013). The SCAS consists of 18 positively worded items and has a reported reliability coefficient (Cronbach's alpha) of 0.89. The scale items are rated on a 5-point scale ranging from 1 (never) to 5 (always), with the options being: never, rarely, often, usually, and always. Items supporting anxiety were scored from 1 to 5, starting with "never" as 1 and progressing sequentially to "always" as 5. As students' scores on the scale increase, their level of anxiety toward science is considered to increase accordingly. Accordingly, the minimum possible score on the scale is 18, while the maximum is 90.

Science Learning Motivation Scale (SLMS)

To determine middle school students' motivation toward science learning, a revised version of the scale originally developed by Tuan et al. (2005) and translated into Turkish by Yılmaz and Çavaş (2007), consisting of 33 items and 6 factors, was used. Principal component analysis conducted by Atay (2014) revealed that the scale has a structure consisting of 6 factors and 23 items. In this study, the 23-item version of the scale was used to determine students' levels of motivation toward science learning. The Science Learning Motivation Scale (SLMS) consists of 23 items, including 19 positively worded and 4 negatively worded statements, and has a reported reliability coefficient (Cronbach's alpha) of 0.80. The items on the scale are rated on a 5-point scale as follows: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree; positively worded items were reverse-scored from 5 to 1 using the same order. For negatively worded items, reverse scoring was applied.

Accordingly, the minimum possible score on the scale is 23, while the maximum is 115.

Semi-Structured Interview Form

For the qualitative data of the study, an interview form was prepared by the researchers, and the structure of this form was followed during the interviews. The semi-structured interviews included questions related to identifying variables, forming hypotheses, and the role of instructional methods and materials used in the classroom in promoting scientific process skills. The questions were reviewed by three independent experts, apart from the researchers, to ensure their appropriateness for evaluating the specified topics. Based on the feedback received (e.g., adding alternative and simplified questions considering the cognitive levels of the students' age group), the revised questions were asked to each interviewed student, and a portion of the qualitative data was collected through this method. No time limitation was imposed during the interviews; participants were given sufficient time to express their opinions, and appropriate environmental conditions (e.g., a quiet room, access to their SPS test responses) were ensured. With the consent of the participants, the interview data were recorded using a voice recorder to be later transcribed into written text in a digital environment. Each interview with the participants lasted approximately 20 to 25 minutes. The questions included in the interview are presented in Appendix 1. The general format of the interview questions and their contribution to the research are additionally presented in Table 2.

Table 2. *Format of the interview questions and their contribution to the Research*

Interview Question	Question Type / Description
Question 1	This question is in the form of an open-ended/short-answer item designed to assess general knowledge related to the concepts of "hypothesis," "hypothesis formation," and "variable."
Question 2	In this question, no specific science concept is directly used. The aim is to reveal students' responses to two different scenarios presented without involving any explicit scientific terminology. (Example scenario presented to the student: A circular cake is to be shared equally among a different number of people, and the student is asked how a hypothesis could be formed regarding this distribution.)
Question 3.1. and Question 3.2	These questions aim to assess students' levels of hypothesis formation skills through scenarios involving commonly used science concepts such as solution and temperature, and the relationship between them. Question 3.1 is a multiple-choice question presented in a purely textual format without any visual elements. Question 3.2 is supported by visual elements and is in the form of an open-ended/short-answer question.

Classroom Observation Form

Observation is one of the most important data collection tools in qualitative research methodology, conducted in natural settings and primarily aimed at examining human behavior (Ekiz, 2003). Conducting observations enables the identification of potential qualitative and quantitative relationships between events (Bouty, 1952; as cited in Karasar, 1998). In this study, participants' reactions and attitudes toward classroom instructional activities and materials were observed in order to identify challenges specifically related to "hypothesis formation" and indirectly to "variable identification" skills. During the development of the observation form, the opinions of a panel of three experts, one of whom was a science teacher, were taken into consideration. The observation forms were typically completed immediately after the lesson, without any interaction with others, by one of the researchers who also served as the participants' science teacher. Where necessary, videos and photographs of participants taken during classroom instructional activities were also added to the observation notes.

Data Collection Process

The study was conducted during the 2022–2023 academic year at the sixth-grade level of a public middle school located in the central district of Nevşehir. At the beginning of the research process, necessary permissions were obtained by sending consent forms to the families of the participating students and by acquiring an ethics committee approval from the university. In the first week of December of the relevant academic year, the Science and Technology Anxiety Scale and the Science Learning Motivation Scale were administered respectively to students in two different sections by the researcher, who was also their science teacher. In the second week of December, the Scientific Process Skills Test was administered to the students, and the data obtained were recorded using the SPSS software. Subsequently, in the first week of January, semi-structured interviews were conducted at different times on the same day with eight selected students. While administering the semi-structured interview form, the necessary explanations were provided to the students, no time limits were imposed, and precautions were taken to prevent the students from influencing one another until all eight interviews were completed. Additionally, follow-up questions were included during the interviews (e.g., example scenarios for hypothesis generation, hints related to the instructional methods used during the lessons, definitions and explanations of variable types, and anecdotes from classroom experiments) to support the research data.

Data Analysis

In a scientific study, obtaining valid and meaningful findings requires working with a high-quality data set. In order for the quantitative data set obtained in this study to be subjected to specific statistical analyses, certain parameters first needed to be identified. Therefore, before proceeding with the analysis of the quantitative data, the dataset was examined in terms of missing values, outliers, and normality assumptions. Normality assumptions for each measurement obtained from the participant group were examined using skewness and kurtosis coefficients. As a result of the analysis, it was determined that the skewness and kurtosis coefficients of all data obtained from the Anxiety Scale, the Motivation Scale, and the Scientific Process Skills Test were within the range of +2 to -2; therefore, the variables were assumed to be normally distributed (George & Mallery, 2010). Therefore, it was decided to use parametric analysis tests in the analysis of the dataset. In the analysis of the data sets obtained in the study, descriptive statistics (such as arithmetic mean, standard deviation, and percentage) and the Pearson correlation coefficient were calculated. For the analysis of the qualitative data obtained in the study, the descriptive analysis method was employed, with particular attention given to presenting both quantitative and qualitative findings for each sub-problem in an integrated manner.

Findings

In this section, the findings obtained from the Scientific Process Skills Test (SPST), the Science Learning Motivation Scale (SLMS), the Science Course Anxiety Scale (SCAS), the semi-structured interview form, and classroom observation notes are presented. An effort has been made to present the quantitative and qualitative findings obtained for each research question in an integrated and coherent manner. However, before presenting the findings related to the research questions, an overview of the quantitative data findings is provided. Therefore, the general findings obtained from the SPST, SLMS, and SCAS are presented first.

Table 3. Descriptive statistics of the data collection instruments used

Variable	*N*	*Minimum Value*	*Highest Value*	*Mean*	*Std. Deviation*	*Skewness*	*Kurtosis*
SPST	*42*	*7*	*20*	*11.79*	*3.05*	*0.815*	*0.133*
SCAS	*42*	*45*	*80*	*61.41*	*8.87*	*0.360*	*-0.680*
SLMS	*42*	*51*	*90*	*66.52*	*9.53*	*0.414*	*-0.507*

According to Table 3, participants' scores on the SPST (11.79) and SLMS (66.52) were below the average, whereas their scores on the SCAS (61.41) were generally above the average. Considering that higher scores on the anxiety scale indicate increased levels of anxiety, it was concluded that, overall, students exhibited a certain degree of anxiety toward science lessons. One of the prerequisites for parametric analysis tests is the assumption of normality, and the skewness and kurtosis values were found to fall within the range of -1.5 to +1.5. Therefore, it was determined that appropriate parametric tests (e.g., t-test, ANOVA, etc.) could be used for analyzing the score sets presented in the table (Tabachnick & Fidell, 2013).

The research question of the study focuses on the current state and deficiencies in the skill of hypothesis formation. Hypothesis formation is an essential component of scientific process skills and requires the formulation of possible solution proposals in response to a given question or problem situation. This is because hypothesis statements necessitate the use of dependent, independent, and controlled variables related to the problem. Therefore, the skill of forming hypotheses is directly related to another scientific process skill: ICV. Furthermore, it can be stated that individuals whose skills in identifying and controlling variables are not well-developed also tend to be inadequate in other scientific process skills, particularly in forming hypotheses. A well-constructed hypothesis should include a claim and be expressible in terms of variables. Among the 25 questions included in the SPST, six items (Questions 3, 7, 11, 18, 20, and 24) are specifically designed to assess the skill of HF. The descriptive data prepared to reveal students' current proficiency in this skill are presented in Table 4.

Table 4. Descriptive statistics for HF skills

Variables	*N*	Min. Value	Max Value	Mean	Std. Deviation	Skewness	Kurtosis
HF Skill Scores	42	2	5	2.86	0.95	0.833	-0.292

According to Table 4, the average score students received on the HF questions was found to be at a moderate level (M = 2.86) out of a maximum of six points. The minimum and maximum scores obtained from the HF questions were 2 and 5, respectively. However, based on the calculated skewness and kurtosis coefficients, it can be stated that this score set is approximately normally distributed. The HF-related questions in which students demonstrated the lowest levels of success are listed in Table 5. Upon examining the findings in this table, it can be stated that, in three out of the six questions, the majority of the participants (N = 42) answered incorrectly—indicating that they struggled with these items.

Table 5. HF questions with the lowest student performance

	Answer Choices			
HF Question No	**A**	**B**	**C**	**D**
3	14*	3	15	10
18	12	15	13*	2
24	3	20	8	11*

**The* correct option for the question

When Table 5 is examined, it is observed that the majority of students selected the incorrect options C and D for the third question related to hypothesis formation. The reason for this is believed to be the initial statement in the question: "a police chief is dealing with reducing the speed of cars." Since the correct option (option A) contains the phrase "driving faster," which presents a contrast, it can be said that students were drawn to the options derived from everyday experiences that felt more relatable and meaningful to them. In other words, it is thought that the students did not fully understand the question or were unable to connect the scenario described in the text with the answer choices.

A similar situation was observed in items 18 and 24 among the HF questions. In both questions, it can be stated that students tended to choose the first option or the one that seemed most reasonable to them, without paying attention to the variables presented in the initial scenarios (e.g., factors affecting fish movement and the dissolution rate of sugar in water). Indeed, classroom observations revealed that the students who answered these

questions incorrectly were mostly among those (approximately twenty) who had reading difficulties or lacked regular reading habits. Moreover, on the day the SPST was administered, it was observed that students in this profile quickly selected option B for item 24. When the researcher—who was also the students' science teacher—asked about the reason for this, the students explained that they based their answer on the fact that "the first sentence mentioned the movement of the fish."
Interview data also revealed similar findings regarding one of the main challenges in developing HF skills in the SPST—namely, students' reading difficulties and lack of reading habits. In addition to the questions listed in the interview form (Appendix 1), the researcher posed a few supplementary questions to create a conversational atmosphere. Specifically, during students' responses to the first three questions (concerning hypothesis formation, the necessity of hypotheses, identifying and classifying variables, etc.), brief questions were also asked regarding their study habits, reading routines, and learning environments at home. The responses to these questions indicated that more than half of the students lacked regular reading habits at home or school, experienced difficulties in reading comprehension, did not demonstrate consistent study practices, and required support in reading and writing activities. Below are excerpts that exemplify these conditions.

R: I noticed that you reread the same part of the question several times—why is that? Is there something unclear in the question?
S4: It seemed a bit confusing to me, so I was checking whether the words in the answer matched what was asked in the question. I always do it this way. Otherwise, I make too many mistakes. It takes time, but it's a good method.
R: So, does your reading usually take this long in your other classes as well?
S4: Yes, I always do it this way.
R: Do you read books outside of your classes? Do you make time for reading?
S4: No, teacher. I don't like writing either. I only read the school books and whatever is assigned in my Turkish lessons.

A similar situation was observed in the responses to questions related to study habits at home. It was noted that students, particularly S4 and S5, expressed a strong aversion to writing activities and showed a clear preference for multiple-choice questions, interactive tasks, and homework assignments instead.

R: Outside of school, is there anyone who helps you when you are doing your homework at home?
S5*: Yes, there is. On some days, I ask my mom for help with the parts I can't do. Or I ask my friend.*
R: So, what do you do if they can't help either? For example, do you look at other books?
S5*: No, I don't. I ask my teacher—if I remember.*
R: Do you read books regularly every day? It might help more with your lessons.
S5*: Yes, you're right, teacher. Maybe it's because I don't read much. I even have a hard time finishing my Turkish class book. But I get very bored when I read.*
R: Okay, I understand—reading feels boring to you. So, let's see—which kinds of homework do you do more quickly and without getting bored?
S5: *What I like the most is when you give us tests, you know—the ones with choices. And the matching ones are really easy, too.*
R: Well then, these questions here (Appendix 1, Question 3.1) also have choices. Why do you think you struggled with them?
S5: *But teacher, the words in these questions are really similar to each other, and there are also some words I don't understand. I struggle with texts like this and with other books too—I have to read them several times to understand.*

To investigate the challenges in developing HF skills, it was also considered that students' affective characteristics might play a role. Therefore, the correlation between HF scores and the sets of scores related to motivation toward science courses and science-related anxiety levels was examined. Information regarding the correlation between HF and motivation levels is presented in Table 6.

Table 6. Correlation between hypothesis formation skill and motivation level

			Mean Score of HF Skill
Mean Score	Motivation	Pearson Correlation (R)	.560
		p	.02*
		N	42

*p<.05

According to Table 6, there is a positive, moderate, and statistically significant correlation between hypothesis formation skill and motivation levels (R = 0.56, p<.05). In other words, as students' level of motivation increases, their average scores in HF skills also tend to rise. It can be stated that the quantitative data obtained from Table 4 and Table 6 are consistent with the qualitative findings (interviews and observations). Observation notes and sample excerpts from interviews related to this correlation are presented below.

"Teacher, last week when we were covering the topic of dependent and independent variables and hypotheses, we had a volleyball match that day. We lost, and I wasn't in a good mood, so I didn't really pay attention in class. So, could we not have an oral quiz today and maybe review the topic instead?" (The whole class agreed)." 13 December 2022

"Teacher, even if we learn these things, how will they be useful to us? I mean, forming dependent-independent hypotheses and such. I don't think it will be useful in real life." January 5, 2023 (This opinion was supported by the majority of the class)."

"Teacher, I'm very happy today. I'm sure I will understand everything we cover in class very well." February 21, 2023.

Table 7 presents the correlation data between HF skill and anxiety levels toward science.

Table 7. Correlation between hypothesis formation skill and anxiety level

		Mean Score of HF Skill
Mean Anxiety Score	Pearson Correlation (R)	-.55
	p	.01*
	N	42

*p<.05

When Table 7 is examined, a moderately negative and statistically significant correlation is observed between HF skill and anxiety score averages (R =-0.55, p<.05). In other words, as students' anxiety levels toward science increase, their hypothesis formation skill scores tend to decrease. It can be stated that the quantitative findings obtained from Tables 4 and 7 are consistent with the qualitative data collected through observations and interviews. Observation notes and selected quotations from interviews related to this correlation are presented below. Based on classroom observations conducted over a period of approximately three months, it was evident that students generally exhibited a certain level of anxiety toward science lessons. It was observed that, even during simple cognitive activities conducted in the classroom (such as making observations, recording findings, categorizing, and comparing), some students either resisted participating or struggled significantly, merely because these activities involved science-related topics or concepts. Although the researcher's pre-activity explanations aimed at reducing student anxiety partially encouraged efforts to develop their scientific process skills, it can be stated that this anxiety tended to resurface in subsequent stages. The following observation anecdotes and interview excerpts are presented as illustrative examples of this relationship.

"Teacher, identifying variables is kind of okay, it's a bit easier, but forming a hypothesis is really hard. I just don't get it. It's always like this in science anyway." 20 December 2022

"I've realized that science just isn't for me. Even if I learn this topic in class now, I forget it by tomorrow. This topic is really hard, teacher." 20 December 2022

"For example, I don't even know what hypothesis formation means. We also cover it in our social studies class, and I kind of understand it during the lesson, but then I forget and can't do it again later." 5 January 2023

"Teacher, forming a hypothesis is really difficult. Like, when they ask about the dependent variable in a question, they give it in the choices, but forming a hypothesis isn't something you can just find like that. It's science, after all. I mean, if we're going to do an experiment, we have to come up with a kind of opening sentence beforehand — that's why it's so hard." 10 January 2023

It can be concluded that sixth-grade middle school students have difficulty in reading comprehension when responding to questions aimed at measuring hypothesis formation skills, and therefore struggle to establish a meaningful connection between the scenario presented in the question stem and the options provided. It was frequently observed that students who lack regular reading habits often make the mistake of identifying common words or expressions between the question stem and the answer choices, rather than reading all the options, and then choosing the first response that seems meaningful to them. Furthermore, hypothesis formation imposes a greater cognitive load on students compared to variable identification and control skills, as it requires them to understand variables and formulate a logical proposition involving these elements; hence, it can be stated that students face difficulties in both multiple-choice and open-ended questions related to this skill. Findings have also revealed that students' affective characteristics may play a role in the development of HF skills. In this context, it has been observed that students with low levels of motivation and high levels of anxiety experience greater difficulty in hypothesis formation.

Discussion and Conclusion

According to the findings of this study, sixth-grade middle school students encounter certain difficulties in developing the scientific process skill of HF. These difficulties may hinder students from effectively acquiring these skills. In another study by Aydoğan Ağmanalmaz (2024), which highlighted the strong relationship between HF and variable identification skills, it was emphasized that similar difficulties were encountered. In the aforementioned study, it was observed that students particularly struggled to determine which factors should be controlled or which variables should be manipulated in experimental setups when applying and developing these two skills. Similarly, in the present study, it can be stated that participants also had difficulty in identifying the variables presented in the examples, which in turn affected their ability to form hypotheses. In another study conducted by Ateş (2005), it was reported that third-year elementary teacher education students were unable to distinguish between dependent and independent variables because they did not fully understand the meanings of the relevant concepts regarding variable identification and control skills.

According to the results of the study, participants were observed to face challenges such as a lack of reading habits and an inability to comprehend or interpret the texts due to linguistic and expressive limitations. It can be stated that students particularly struggled to establish cause-and-effect relationships when the question texts were relatively long, which in turn made HF more difficult. The abstract concepts presented in the questions of the SPST may have contributed to the difficulties experienced by students in this age group when forming hypotheses. Indeed, it has been determined that the limited cognitive abilities of students at this age level negatively affect skills such as hypothesis formation, identifying variables, data analysis, and graphing (Ateş & Bahar, 2002). It has been evaluated that the format (open-ended/multiple-choice) and structure (with or without visual support) of the questions may influence students' performance. It was observed that students performed better on questions enriched with visual elements. Analyses revealed that students' affective characteristics also played a role in the development of hypothesis formation skills. In this context, it can be stated that as students' motivation toward science increases, their hypothesis formation skills also

improve, whereas an increase in anxiety levels leads to a decrease in these skills.
It can be stated that this study conducted with sixth-grade middle school students yielded similar results to the study by Temiz and Tan (2009) conducted with ninth-grade students. At both educational levels, students were found to exhibit deficiencies in these fundamental scientific process skills and to encounter specific challenges. Both middle and high school students experience conceptual difficulties in hypothesis formation and identifying variables. In particular, students struggle to accurately define and distinguish between dependent, independent, and control variables.

One of the key parameters of scientific literacy is scientific process skills. Among these skills, the ability to formulate hypotheses is considered a higher-order skill. Therefore, fostering and developing this skill in science classrooms is of great importance. This is because hypothesis formulation is frequently required in experimental and observational activities, which are integral to the nature of science. Therefore, these skills should be taught to students not only cognitively, but also with consideration of affective factors such as attitude, motivation, and anxiety. This study also aimed to reveal the influence of certain affective characteristics related to science on the development of hypothesis formulation skills. The participants' attitudes toward science directly influence the process of developing these skills. Students with positive attitudes toward science tend to be more active in class and more open to learning new concepts and skills. In their study, Yenice et al. (2012) stated that an increase in students' motivation toward science led to greater interest in science courses and, consequently, improved academic performance in science. Altınok (2004) found that students' attitudes toward science significantly influenced their achievement motivation, and that negative attitudes could adversely affect their motivation to succeed. In a study examining the effects of anxiety and evaluation threats on student performance and motivation, Hancock (2001) demonstrated that anxious students tended to perform at lower levels. Therefore, designing instructional strategies that engage and motivate students is vital for improving their attitudes toward science and enhancing their motivation to learn. All of these factors must be carefully addressed in a way that supports students in developing their hypothesis formulation skills.

Ethics statement

This study was written using a portion of the data from the master's thesis titled "*Challenges in the Development of Sixth Grade Middle School Students' Skills in Identifying Variables and Formulating Hypotheses*", prepared by Burcu Aydoğan Ağmanalmaz under the supervision of Dr. Mahmut Polat.

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Appendix 1. Semi-Structured Interview Form

1. How do you define the hypothesis (hypothesis statement), the measured variable, the variable that is changed, and the variable that is kept constant? Can you explain each of them to me in a few sentences? (Facilitating alternative question: You can also explain these concepts with examples. What comes to your mind about them?)

………………..…………………………………………………………..

2. Ahmet orders a round cake from a bakery for his birthday party. A group of 10 friends, including Ahmet, start eating this cake. If 15 people ate the same cake;

a) How would the thickness of each slice of the cake change?
………………………………………………………………………

b) What causes the thickness of the cake slice to change?
………………………………………………………………………

3.) I want you to read the two questions presented below (3.1 and 3.2) carefully and answer the sub-questions under each one. Then I want you to indicate which one you had the most difficulty with. (You can ask me if there are any unclear parts.)

3.1 Murat wants to investigate whether the temperature of water affects the amount of sugar that can be dissolved in water. He pours 50 millilitres of water into each of four identical glasses. He pours water at 0°C into one glass, and water at 50°C, 75°C and 95°C into the other glass. He then pours as much sugar as can be dissolved into each glass and mixes it.

a) Which hypothesis do you think could be tested in this study?

a. The more sugar is mixed in water, the more it dissolves.

b. The more sugar dissolves, the sweeter the water.

c. The higher the temperature, the more sugar dissolves.

d. The more water is used, the higher its temperature.

b) Which variable do you think can be controlled in this study??

a. The amount of sugar dissolved in each glass.
b. Amount of water put in each glass.
c. Number of cups.
d. Water temperature.

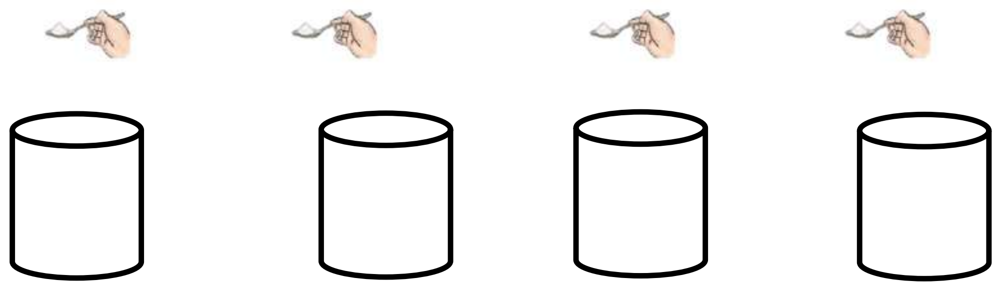
c) What do you think is the measured variable of the study?

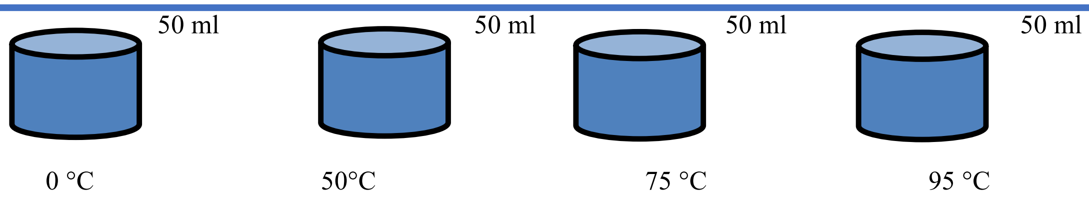
a. The amount of sugar dissolved in each glass.
b. Amount of water put in each glass.
c. Number of cups
d. Water temperature.

d) What do you think is the variable that was changed in the study?

a. The amount of sugar dissolved in each glass.
b. Amount of water put in each glass.
c. Number of cups
d. Water temperature.

3.2 Murat wants to investigate whether the temperature of water affects the amount of sugar that can be dissolved in water.





Murat puts enough sugar to dissolve in the four different experimental setups given above and mixes them. In this research;

a) Dependent variable?

……………………………………………………………………………….........

b) Independent variable??

………………………………………………………………………………

c) What are constant variables??

……………………………………………………………………………….

d) Write a Hypothesis statement for this situation.

………………………………………………………………………………