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Identifying the difficulties in developing hypothesis formation skills in science classes

Burcu Aydoğan Ağmanalmaz[1], Mahmut Polat*[2]

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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[1]*MSc, Department of Science Education, Nevsehir Hacı Bektas Veli University, Nevşehir, 50300, Türkiye, E-mail: burcuayydgn@gmail.com, ORCID ID: 0000-0003-4482-2842*
[2]*PhD, Department of Science Education, Nevsehir Hacı Bektas Veli University, Nevşehir 50300, Türkiye. E-mail: mpolat@nevsehir.edu.tr ORCID ID: 0000-0003-3058-9701*
**: corresponding author*

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.

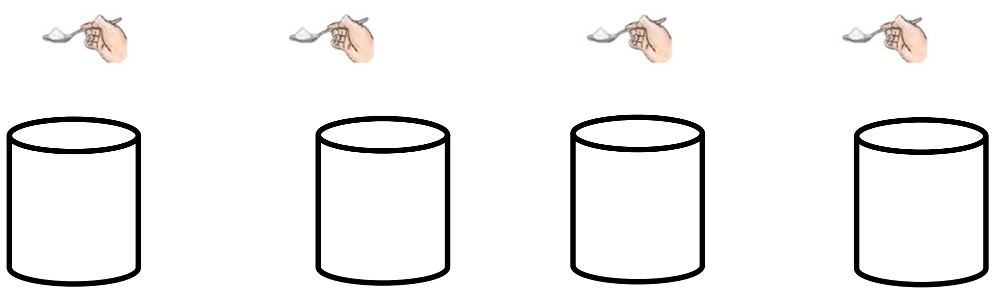
c) What do you think is the measured variable of the study?

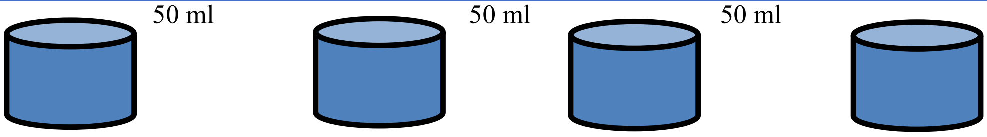
a. The amount of sugar dissolved in each glass.
b. Amount of water put in each glass.
c. Number of cups
d. Water temperature.

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.

………………………………………………………………………………