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Author Contribution Statement

[1] **Mahmut POLAT** *Assist. Prof.Dr.,* *Nevşehir Hacı Bektaş Veli University* *Nevşehir, Türkiye*	Conceptualization, literature review, methodology, implementation, data analysis, translation, writing, auditing, and editing processes
[2] **Burcu AĞMANALMAZ** *PhD. Student* *Nevşehir Hacı Bektaş Veli University* *Nevşehir, Türkiye*	Literature review, methodology, implementation, translation, writing, auditing, and editing processes

Abstract

This study aims to develop the Interactive Mathematics Learning Model that integrates digital tools with Realistic Mathematics Education. The model is designed specifically for teaching secondary school mathematics and consists of three basic components to make the mathematics learning process more meaningful, interactive and permanent: contextual problem scenarios, mathematical modeling and interactive discovery, and a collaborative and adaptive learning environment. The main purpose of the model is to provide middle school students with mathematical thinking skills through real-life problems, to develop mathematical models and to allow them to test these models with digital manipulatives. The model is supported by digital tools such as virtual reality environments, game-based learning platforms and artificial intelligence-supported analysis systems. Students create mathematical models using digital simulations in their problem-solving processes and make abstract concepts concrete by testing these models. The integration of the model into secondary school mathematics teaching processes aims to develop mathematical thinking skills by providing students with meaningful learning experiences. In this context, it is expected that the model will be tested with pilot applications, its effectiveness will be evaluated and it will offer an innovative approach in mathematics teaching.

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Research Article

Challenges in Enhancing Sixth-Grade Students' Skills in Identifying and Controlling Variables [*]

Mahmut POLAT [1] **Burcu AĞMANALMAZ** [2]

Abstract

The aim of this study is to examine the current state of sixth-grade middle school students' skills in identifying and controlling variables and to determine the challenges they face in developing these skills. The participant group consisted of 42 students enrolled in a middle school located in the city center of Nevşehir. An explanatory mixed-methods design was employed in the study. A mixed-methods design involves the collection and integration of both qualitative and quantitative data. In this context, to obtain detailed and comprehensive data regarding the challenges in developing variable identification and control skills, the quantitative phase of the study involved administering 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 based on predetermined criteria. Also, classroom observations conducted over a period of 16 weeks were used to achieve data triangulation. According to the findings derived from the analysis of both quantitative and qualitative data, students' average score on the Identifying and Controlling Variables (ICV) questions was found to be moderate out of a maximum of 14 points. The minimum and maximum scores obtained on the ICV questions were 3 and 11, respectively. It was observed that students had difficulty identifying the variables to be manipulated and the factors that needed to be controlled in experimental setups. It can also be stated that they struggled to make scientific predictions based on the relationships between observations and variables. These difficulties are considered to stem from the underdevelopment of students' scientific thinking and critical evaluation skills. Furthermore, it was concluded that students' motivation toward science directly influenced their learning processes, and those with higher levels of motivation participated more actively in class and were more open to learning new concepts.

Keywords: Identifying and controlling variable, science teaching, scientific process skills, secondary school education

1. INTRODUCTION

Science and technology are rapidly advancing in our era and are becoming increasingly complex. Individuals who are able to follow these developments and adapt to them are regarded as representatives of modern societies. Individuals who possess skills such as logical thinking, problem-solving, accessing information, questioning events, and understanding technological innovations will become members of future modern societies. In order to cultivate individuals with these abilities, the importance of experimental, observational, and abstract concepts, as well as the relationships between concepts, is particularly emphasized in science education. Science education aims not only to transmit knowledge but also to promote students' cognitive and affective development, enabling them to acquire the skills needed to cope with real-life problems. The primary objective of the science curriculum is to raise scientifically literate individuals (Education and Training Board Presidency

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[1] *Assist.Prof.Dr., Nevşehir Hacı Bektaş Veli University Faculty of Education, mpolat@nevsehir.edu.tr , Nevşehir, Türkiye*
[2] *PhD. Student, Nevşehir Hacı Bektaş Veli University, burcuayydgn@gmail.com , Nevşehir, Türkiye*
Corresponding Author e-mail adress: mpolat@nevsehir.edu.tr

[ETBP], 2018). One of the most significant and common goals of education is to teach thinking. The ultimate purpose of schools at all levels and the science courses offered within them is to fulfill this goal.

One way to promote thinking strategies is through the use of scientific process skills (SPS) (Padilla, 1990). SPS are sets of abilities that encompass scientists' capacity to make sense of nature and their cognitive processes (Taşkın & Koray, 2006). These skills can be regarded as a form of scientific thinking and support features such as inquiry, generation of ideas, and engagement in scientific communication. Individuals with well-developed SPS may be more adaptable to rapid 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. SPS can be briefly defined as the abilities that scientists use in conducting their work. Although various classifications exist in the relevant literature, it is generally accepted that there are thirteen SPS in total, with eight considered basic and five regarded as advanced (Çepni, 2023).

Science curricula and course content around the world are continuously being updated to equip students with these skills. In our country, the 2005 Science and Technology curriculum and all subsequent programs have emphasized the importance of educating every student as a scientifically literate individual, regardless of their individual differences. A scientifically literate individual is someone who investigates, questions, makes informed decisions, demonstrates creativity, possesses self-confidence, is open to collaboration, and communicates effectively. Such individuals not only benefit themselves but also contribute positively to the society in which they live.

SPS are not only a means to understand science learning and scientific inquiry, but also a significant goal of education itself (Anagün & Yaşar, 2009). In lifelong learning processes, individuals are required to learn, analyze, and evaluate events they encounter under various conditions; therefore, SPS play a critical role in facilitating meaningful learning (Bilgin, 2006). In inquiry-based learning environments, the variable identification phase—where not only applicable hypotheses are developed for the posed problem but also the rationale behind planned activities is questioned—holds significant importance in the context of active learning practices.

This study focuses on the SPS of identifying and controlling variables (ICV). The ICV skill plays a key role in the development of multiple scientific process skills, particularly in hypothesis formulation. This is because the skill of formulating hypotheses—regarded as claims or proposed explanations for natural phenomena or specific situations—requires the use of ICV skills (Hughes & Wade, 1993). When constructing a hypothesis, it is essential to focus not on the accuracy of the explanation itself, but rather on structuring the statement based on variables that reflect the cause-and-effect relationship—namely, dependent, independent, and controlled variables. If such a process is followed, the experimental setup required to test the validity of any hypothesis proposed during the research process can be constructed more easily. As can be inferred from this, it can be stated that ICV skills also contribute to the development of the scientific process skill of designing experiments (Bayraktar et al., 2006).

In Turkey, most studies focusing on SPS have been conducted using quantitative research approaches, generally aiming to reveal their relationship with variables such as students' academic achievement, problem-solving, 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 employing qualitative research approaches—which allow for more detailed and comprehensive data collection—focused on identifying and developing SPS in science courses. Yet, it is essential—within the relevant literature—to examine these skills in greater depth and in isolation, as they involve complex cognitive and affective processes. Therefore, this study aims to explore the possible reasons why the skill of ICV

may not be sufficiently developed in science courses, by placing this skill at the center of investigation. In this context, the study sought to answer the following research questions (RQs):
RQ1. What is the current state of sixth-grade students' skills in ICV?
RQ2. What challenges do students face in developing their ICV skills?

2. METHOD

2.1. Design of the Research

An explanatory mixed methods design was employed in the study. A mixed methods design is a research framework in which both qualitative and quantitative data are collected and integrated (Fraenkel et al., 2012; Gay et al., 2012). The aim of this design is to ensure a more detailed and comprehensive understanding of a phenomenon by leveraging the strengths of both qualitative and quantitative methods (Mills & Gay, 2016). The explanatory mixed methods design involves first conducting a quantitative phase, analyzing the results, and then reinterpreting those results in more depth through a subsequent qualitative phase (Creswell, 2017).

In this study as well, scientific process skills—one of the key dimensions of scientific literacy—were placed at the center of investigation. In the quantitative phase of the study, in order to obtain detailed and comprehensive data by considering the challenges in developing variable identification and hypothesis formulation skills, the sample (*N*=42) was administered the Scientific Process Skills Test (SPST), the Science Anxiety Scale (SAS), and the Science Learning Motivation Scale (SLMS). In the qualitative phase of the study, semi-structured interviews were conducted with eight students selected according to predetermined criteria. Additionally, data triangulation was sought through classroom observations conducted over a period of 16 weeks.

2.2. Participants

The participants of the study consisted of sixth-grade students enrolled in a middle school located in the city center of Nevşehir. Although the study group initially consisted of 45 students, this number was reduced to 42 during the research process due to various reasons, including school transfer, learning difficulties, and the inability to administer 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 implementation was conducted was selected through convenience sampling. Convenience sampling refers to selecting participants from easily accessible and applicable groups due to certain limitations in terms of time, cost, and labor (Büyüköztürk et al., 2024). To collect the quantitative data, the designated scales were administered to 42 students (20 female, 22 male). Information regarding the eight students who participated (P) in the semi-structured interviews is presented in Table 1. These students were selected based on gender distribution, scientific process skills test scores, and scores obtained from other data collection tools. In this way, the opinions of students of different genders with high and low scores were sought.

Table 1. Descriptive information of the interview 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

2.3. Data Collection Tools

This section presents comprehensive information about the data collection instruments employed in the study. These instruments were selected in alignment with the research objectives and sub-questions, and were structured to address both the quantitative and qualitative dimensions of the research. Each measurement tool is described in detail, including its role in the data collection process, the type of variable it measures, the participant group to which it was administered, and its validity and reliability properties. In this context, instruments aimed at measuring scientific process skills, science-related anxiety, and motivation toward science learning are introduced, along with interview protocols and classroom observation procedures.

2.3.1. Scientific process skills test (SPST)

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

2.3.2. Science course anxiety scale (SCAS)

To determine students’ anxiety levels regarding science courses, the 5-point Likert-type SCAS developed by Kağıtçı (2014) was used in the study (Kağıtçı & Kurbanoğlu, 2013). The SCAS consists of 18 positively worded items, and its reliability coefficient (Cronbach’s alpha) has been reported as 0.89. The items of the scale are rated on a 5-point scale ranging from "never" to "always," with the intermediate options being "rarely," "often," and "usually." The items reflecting anxiety were scored from 1 to 5, starting with "never" as 1 and increasing incrementally up to "always" as 5. As students’ scores on the scale increase, it is assumed that their level of anxiety toward science increases accordingly. Accordingly, scores on the scale can range from a minimum of 18 to a maximum of 90.

2.3.3. Science learning motivation scale (SLMS)

To determine middle school students’ motivation toward science learning, a modified 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 had a 6-factor structure comprising 23 items. In the present study, the 23-item version of the scale was used to assess students’ motivation toward science learning. The SLMS consists of 23 items, including 19 positively worded and 4 negatively worded statements, and its reliability coefficient (Cronbach’s alpha) has been reported as 0.80. The items were rated on a 5-point Likert scale: "strongly disagree," "disagree," "neutral," "agree," and "strongly agree." Positively worded items were scored in the same order, from 1 to 5. For negatively worded items, reverse scoring was applied. Accordingly, scores on the scale can range from a minimum of 23 to a maximum of 115. The sub-dimensions of the scale include self-efficacy, active learning strategies, value of science learning, performance goal, achievement goal, and encouragement in the learning environment.

2.3.4. 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 on variable identification, hypothesis formulation, and the role of instructional methods and materials used in the classroom in fostering scientific process skills. The questions were reviewed by three independent experts to ensure their appropriateness for evaluating the specified topics, independently from the researchers. Based on the feedback received (e.g., considering the students' age group and cognitive development, and including alternative and simplified questions), the questions were revised and asked to each student interviewed, and part of the qualitative data was collected through this method. No time constraints were imposed during the interviews; participants were given sufficient time to express their ideas, and appropriate environmental conditions were ensured (e.g., a quiet room, access to their responses on the SPS test). With participants' consent, the interviews were audio recorded and later transcribed into written format on a computer. Each interview lasted approximately 20 to 25 minutes. Detailed information regarding the interview questions is presented in Table 2.

Table 2. Format and contribution of the interview questions

Interview Questions	Question Type / Description
Question 1	This question is designed in an open-ended/short-answer format to assess general knowledge about the concepts of "variable," "types of variables," and "hypothesis."
Question 2	No specific science concept is explicitly used in this question. The aim is to assess the student's response to two different situations—presented without any scientific terminology—such as the equal sharing of a circular cake among different numbers of people.
Question 3.1. and Question 3.2	These questions aim to assess students' levels of ICV skills through scenarios involving the concepts of solution and temperature, which are frequently used in science classes, as well as the relationships 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 with visual elements and is designed in an open-ended/short-answer format.

2.3.5. Classroom observation form

Observation is a data collection tool conducted in natural settings, primarily aimed at examining human behavior, and is considered one of the most essential instruments in qualitative research (Ekiz, 2003). Conducting observations allows researchers to identify possible qualitative and quantitative relationships between events (Bouty, 1952, as cited in Karasar, 1998). In this study, participants' responses and attitudes toward classroom instructional activities and materials were observed to identify the challenges they face in developing scientific process skills. During the development of the observation form, feedback from a panel of three experts—including a science teacher—was taken into account. The observation forms were generally completed immediately after the lesson, without any interaction with others, by one of the researchers, who was also the participants' science teacher. When necessary, videos and photographs of participants during classroom instruction were also added to the observation notes.

2.4. Data Collection Process

The study was conducted during the 2022–2023 academic year with sixth-grade students at a middle school located in the city center of Nevşehir. At the beginning of the research process, necessary permissions were obtained by distributing consent forms to the students' parents and acquiring ethical approval from the university's ethics committee. In the first week of December, the SCAS and the SLMS were administered, respectively, to students from two different sections by the researcher, who was also their science teacher. In the second week of December, the SPST was administered to the students, and the data obtained were recorded using the SPSS software. In the first week of January, semi-structured interviews were conducted with eight selected students at different times on the same day. During the implementation of the semi-structured interview form, students were provided with necessary explanations, no time limits were imposed, and precautions were taken to prevent students from influencing each other until all eight interviews were completed. Additionally, follow-up questions were included during the interviews (e.g., hints related to instructional methods, definitions and explanations of variable types, and anecdotes about classroom experiments) to enrich the data collected for the study. To ensure data triangulation, classroom observations were conducted for 16 weeks throughout the term during science lessons. These classroom observations began in the first week of November and continued until the last week of March.

2.5. Data Analysis

In scientific research, obtaining valid and meaningful findings requires working with a high-quality data set. In order to subject the quantitative data obtained in this study to certain statistical analyses, it was first necessary to identify specific data parameters. Therefore, before proceeding with the analysis of the quantitative data, the data set was examined in terms of missing values, outliers, and assumptions of normality. The normality assumptions for each measurement obtained from the participant group were evaluated through skewness and kurtosis coefficients. Based on the analysis, it was determined that the skewness and kurtosis coefficients of all data obtained from SCAS, SLMS, and SPST 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 data analysis. In the analysis of the data sets obtained in the study, descriptive statistics (mean, standard deviation, percentage, *etc*.) and the Pearson correlation coefficient were calculated. For the analysis of the qualitative data, the descriptive analysis method was used, and care was taken to present the quantitative and qualitative findings for each sub-problem in an integrated manner.

3. FINDINGS

In this section, findings obtained from SPST, SLMS, SCAS, the semi-structured interview form, and classroom observation notes are presented. Efforts were made to present the quantitative and qualitative findings related to each sub-problem in an integrated manner. However, before presenting the findings related to the research questions, an overview of the quantitative data was provided. Therefore, general findings from the SPST, SLMS, and SCAS were 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, while their scores on the SCAS (61.41) were generally above the average. Considering that higher scores on the anxiety scale indicate higher levels of anxiety, it was concluded that students generally exhibited a certain level of anxiety toward science courses. One of the prerequisites of parametric analysis—the assumption of normality—was met, as the skewness and kurtosis coefficients were observed to fall within the range of –1.5 to +1.5. Therefore, it was concluded that the parametric tests (e.g., t-test, ANOVA) could be applied to the score sets presented in the table (Tabachnick & Fidell, 2013).

The research question of the study focuses on the current state and deficiencies in students' skills of ICV. The ability to identify variables is a crucial component of scientific process skills, as it involves the capacity to recognize variables and understand their effects on outcomes when solving problems. Moreover, it can be stated that individuals with underdeveloped skills in identifying and controlling variables tend to perform inadequately in other scientific process skills, particularly in hypothesis formulation. This is because a well-constructed hypothesis should contain a claim and be expressible in terms of variables.

Of the 25 items included in the SPST, 14 items (Items 2, 5, 8, 9, 10, 12, 13, 14, 15, 16, 21, 22, 23, and 25) are related to the skill of identifying and controlling variables. Descriptive data reflecting students' current level of this skill are presented in Table 4.

Table 4. Descriptive statistics for the skill of ICV

Variables	*N*	Minimum Value	Highest Value	Mean	Std. Deviation	Skewness	Kurtosis
ICV Skill Scores	42	3	11	6.69	1.91	0.313	-0.479

According to Table 4, the average score students received from the ICV items was found to be moderate (6.69) out of a maximum of 14 points. The minimum and maximum scores obtained from the ICV items were 3 and 11, respectively. Moreover, based on the observed skewness and kurtosis coefficients, the distribution of this score set can be considered approximately normal. The ICV-related items in which students demonstrated the lowest performance are listed in Table 5. Examination of the findings in this table reveals that, in 5 out of the 14 items, at least half of the participants (*N*=42) answered incorrectly, indicating that they had difficulty responding to these particular items.

Table 5. ICV items with the lowest student performance

	Question Options			
ICV Question No	**A**	**B**	**C**	**D**
2	17	12	-	13*
8	3	20	8	11*
12	9	12*	6	15
16	13	9	15*	5
21	16	6	12*	8
23	12	19*	4	7

** Correct option for the question*

When the findings in Table 5 are evaluated alongside the qualitative data (interviews and observations), it can be suggested that students' difficulties with Items 8, 12, and 21 may stem from the wording used in the question texts. In all three items, the phrase "Which variable is being controlled?" may not have been fully understood or may have been misinterpreted by the students. It is considered that expressions commonly used in Turkish, such as "voltage tester" or "you should cross the street after checking the traffic," may have confused students in this age group. The everyday use of the word "control" to mean examining or checking a situation may have led students to confuse it with the concept of the dependent variable being investigated.

In Item 2 of the ICV test, the presence of multiple variables that could affect a specific situation (e.g., the distance a car can travel—both the car's weight and the engine volume) may have been challenging for students in this age group, whose abstract reasoning skills are not yet fully developed. Additionally, the phrase "per liter" used in the question text may have evoked different interpretations among students, particularly in terms of proportional reasoning. Therefore, it can be concluded that students also had difficulty with this item.

Some findings from the semi-structured interviews with students also suggest that the aforementioned language- and expression-related difficulties may negatively affect students' performance in scientific process skills. As understood from the interview data, when explanatory statements were provided by the researcher—for instance, clarifying that the controlled variable refers to the constant variable or that the independent variable is the one manipulated during the experiment—students were observed to respond to SPS items more easily. Below are sample excerpts related to the situations described above (R: Researcher, P: Participant).

R: Please take a look at Question 3 on the paper on the table and try to answer it. If there’s anything you don’t understand, feel free to ask me.
P_7: I know that a hypothesis is a proposed idea, but I don’t know what "test" means, teacher.
R: Okay. "To test" means to examine or check an object or an idea to determine whether it has the necessary qualities. Now, read it again with that in mind and try to answer.
P_7: If "to test" means to try or examine, then I think this question is about the relationship between temperature and how sugar dissolves. It’s testing that relationship. My answer is option C.

A similar situation can also be exemplified by the dialogue between the student and the researcher regarding option B of Question 3.1 during the interviews.

P_5: The answer to this one is C. But the other one… hmm. (The student reads option B of Question 3.1 and thinks.)
R: How did we define the controlled variable? Do you remember?
P_5: Hmm, what was it... Isn’t it the one we investigate? The one we control, where we wait for the results.
R: Are you sure? What do we control in an experiment? Remember, there are some things we don’t change at all. We keep them constant so that our results are clearly observable.
P_5: Oh, right—those that don’t change in the experiment, the constants. So in this case, it’s the amount of water in each glass. Teacher, what were the measured and the manipulated variables again?
R: The manipulated variable is the one we change, which we call the independent variable. The measured variable is the one that changes depending on what we manipulate—that’s the dependent variable. Now you can review the question again with that in mind.
P_5: Okay then, the measured variable is the amount of sugar, and the manipulated variable is the temperature of the water.
R: Alright, you can move on to the next question.

Classroom observations have also revealed that the language- and expression-related problems previously mentioned—such as the use of different terms and labels interchangeably and the influence of common everyday meanings (e.g., voltage tester) —are perceived by students as sources of difficulty. It can be stated that the inconsistent use of terms for dependent, independent, and controlled variables across different textbooks and instructional materials poses a challenge for students. Examples of findings obtained from regular classroom observations are presented below.

"Teacher, in the practice books they ask about dependent and independent variables. But sometimes they use the term ‘influencing variable,’ and that’s when I get confused. If they asked like we learned in class—saying ‘dependent variable’—I could answer right away. That’s why I couldn’t solve that question in the exam." (December 14, 2022)

Another ICV item on which students showed the lowest performance was Item 16. The use of a purely textual format in both the stem and the options of the question may have posed a challenge for the students. Indeed, Questions 3.1 and 3.2, which were presented during the interviews, addressed the same scenario but differed in terms of format. While one of the questions was prepared entirely in a textual format, the other was enriched with visual elements, making it easier to follow. Both of these questions were asked to all students during the semi-structured interviews. The majority of the eight students performed better on the question that combined textual content with visual elements such as diagrams and illustrations. It was noted that students were particularly able to answer the question more easily by following the diagrams and illustrations.

R: While working on those two questions (3.1 and 3.2) a moment ago, which one did you find more difficult? Could you explain it to me?

P_3: Teacher, the one with the diagram—that one was easier for us, I think. I looked at the pictures, made comparisons, and quickly wrote down the dependent and independent variables. But in the previous question, I had to read all the text. I might mix them up—it feels like everything is placed side by side.

P_1: In my opinion, the easiest one between the two was the one below (Question 3.2). You just look at the picture, find what's different, and write the answer by identifying what stays the same in the figure. The ones that stay the same are already the controlled variables. The ones we change with our own hands are the independent variables. Everything is clear.

Classroom observations have also revealed that one of the underlying reasons for the difficulties students experience with ICV items is related to the question format—whether it is presented in plain text or enriched with visual elements. Following a laboratory experiment conducted by the teacher during class, two different versions of the same question were presented. When the question was made clear, understandable, and supported with visuals, students were able to answer it more easily. The following anecdotal evidence may be presented as support for this situation.

"Teacher, in this question, all the metals were placed in the same water, so I thought their final temperatures would be the same. That's why I assumed the candles would melt at the same rate—I didn't think about thermal conductivity. But when you drew the question as if each metal was placed in a separate container, then I understood that because the conductivities are different, the melting times would also differ." (February 13, 2023)

"Teacher, earlier you gave us the written version, but it was difficult. After we did the experiment (the one about heat conduction in different metals), and you showed it with a diagram here, I remembered the question. The answer came to me right away." (February 13, 2023)

Another challenge in developing ICV skills emerged through findings obtained from both interview and observation data. The researcher, who was also the science teacher of the participant group, frequently used numerous example situations and scenarios throughout the lessons, particularly aimed at enhancing students' ability to identify variables. These examples were sometimes drawn from everyday life (e.g., "What are the variables that influence the purchase of a car?"), and at other times, they were based entirely on science-related topics and concepts (e.g., "What are the factors affecting the solubility of salt in water?"). Classroom observations conducted over a three-month period revealed that students were less successful in answering questions involving scientific topics and concepts—only about half of such questions were answered correctly during the process. In contrast, it was observed that the variables embedded in examples derived from daily life were identified easily by the vast majority of students. It can be stated that dependent, independent, and controlled variables in such scenarios were identified correctly and with ease. The following anecdotal statements may serve as evidence for this situation.

"Teacher, wouldn't it be better if you always asked questions from things we already know—like examples from outside school, I mean daily life situations." January 6, 2023, Science Lab.

"What are the variables or features that might increase the speed of a computer?" While identifying variables for three computers of the same brand, Ö.K., who had previously been reluctant to respond, jumped up and eagerly listed all the relevant features. Later, Ö.K. stated, "Teacher, when it's not about science, the answers just flow." January 5, 2023, Science Lab.

The second item in the semi-structured interview form was also designed to assess students' ICV skill levels using real-life scenarios. Almost all of the students were able to answer this question with ease. In both situations, students were able to identify and list the factors that influenced the thickness of the cake slices. Similarly, the constant elements in both situations were identified with ease. The reasons expressed by the students regarding this situation were found to be consistent with the findings obtained from classroom observations.

P_7: "Teacher, I can answer this question too. It’s clear which one is dependent and which one we control. The number determines whether the cake slices are thick or thin. I’m the one who decides or changes some things. There’s nothing related to school subjects in this."

P_8: "Teacher, these questions feel easy to me. They’re similar to the examples we did in class. I can also answer them when they include science-related terms, but maybe my classmates might find them harder. When it’s science, it might feel scary. But here, it’s just cake slices."

P_1: "It’s not hard here because the situation is clear. The things about cake thickness that we change are the dependent variables. The independent variable is the person arriving. The same cake means it’s the constant. You don’t need to know science here. That’s why it’s not hard."

Considering that students’ affective characteristics may also play a role in the challenges related to developing ICV skills, the correlation between students’ ICV scores and their motivation toward science courses and anxiety levels related to science was examined. Table 6 presents the correlation findings between ICV scores and levels of motivation.

Table 6. Correlation between variable ıdentification skill and motivation level

		Mean Score of Variable Identification Skill
Mean Score of Motivation	Pearson Correlation (R)	0.750
	p	0.01*
	N	42

**p*<.05

According to Table 6, there is a statistically significant, strong, and positive correlation between variable identification skill and motivation level (R=0.75, $p<.05$). In other words, as students’ motivation levels increase, their mean scores on variable identification skill also tend to increase. It can be stated that the quantitative data obtained from Tables 4 and 6 align with the qualitative findings (i.e., interviews and observations). Relevant anecdotal notes from classroom observations and sample quotations from interviews are presented below in support of this relationship.

"Teacher, I don’t feel like paying attention today. I had a fight with my parents yesterday, and I’m already feeling down." December 20, 2022

"Teacher, we’re really tired—it’s exam week, grades are being announced and everything. We’re exhausted. Maybe we could skip starting a new science topic today?" January 6, 2023

"Teacher, are we going to do variables again today? Is it going to be about science? Can we play a game instead?" December 22, 2022

P_6: "Teacher, I wish you always asked questions like this one—like about cake or computer speed. There’s nothing like pressure or solutions in it, so it’s really easy."

P_5: "Oh no, here’s another one of those questions (referring to Question 3.1). This one’s not like the previous one. Let me look at it—this one has science class topics. I don’t want to mix up dependent and independent again."

Table 7 presents the correlation between variable identification skill and students’ levels of anxiety toward science.

Table 7. Correlation between variable identification skill and anxiety level

		Mean Score of Variable Identification Skill
Mean Score of Anxiety	Pearson Correlation (R)	-0.53
	p	0.02*
	N	42

**p*<.05

Examining Table 7, a statistically significant, moderate, and negative correlation was found between variable identification skill and anxiety score averages (R=-0.53, p<.05). In other words, as students' anxiety levels related to science increase, their scores in variable identification skill decrease. The quantitative data obtained from Tables 4 and 7 appear to be consistent with the qualitative findings gathered from interviews and classroom observations. Anecdotal notes from classroom observations and sample quotations from interviews supporting this relationship are presented below.

"Teacher, I don't want to answer this question (about factors affecting bulb brightness). Everyone laughs at me afterwards. I don't want them to make fun of me again after science class." January 4, 2023

"Teacher, I didn't understand today's topic (identifying variables), and I couldn't say anything in class. This always happens in science lessons. Can you please explain it to me again when you're free?" February 9, 2023, during recess

P_7: "Here come the questions I'm afraid of again. The cake question was nice, teacher. Where did these come from—solution, heat, and temperature?"

This study, focusing on variable identification skill—a key component of scientific process skills and scientific literacy—reveals that middle school students face certain difficulties in this area. It was observed that students had difficulty understanding variable identification questions when unfamiliar terminology was used, leading to incorrect responses or extended time spent on the tasks. It can also be stated that certain linguistic features stemming from the Turkish language may pose additional challenges in the development of ICV skills. The format and design of the questions were found to influence students' performance, with higher success observed in questions enriched with visual elements. The findings also suggest that students' affective characteristics may influence the development of ICV skills. In this context, it was observed that students with low motivation toward science and high levels of anxiety experienced greater difficulty in identifying variables.

4. DISCUSSION and CONCLUSION

According to the findings of this study, sixth-grade middle school students were found to face certain difficulties in the scientific process skill of variable identification and control. These difficulties may hinder students from acquiring these skills effectively. First, in terms of variable identification skills, students struggle to determine which factors need to be controlled and which variables should be manipulated in experimental setups. These deficiencies limit students' ability to accurately interpret experimental results and draw valid conclusions. It can be stated that students have difficulty understanding questions related to variable identification due to language and expression. Moreover, the abstract concepts presented in the questions were found to be challenging for students in this age group in terms of identifying variables. The format (open-ended/multiple-choice) and structure (supported or unsupported with visual elements) of the questions were evaluated to influence students' performance. In particular, students were observed to perform better on questions enriched with visual elements. The analyses also revealed that students' affective characteristics play a significant role in the development of ICV skills. In this context, it can be stated that as motivation toward science increases, ICV skill levels also increase, whereas higher levels of anxiety are associated with lower ICV performance.

It can also be stated that while identifying dependent, independent, and controlled variables for a given event or situation, the participating students were simultaneously attempting to establish and test cause-and-effect relationships. This is because the skill of ICV plays a critical role in establishing the causal chain between an independent (cause) and a dependent (effect) variable within a given situation. According to the findings obtained from the present study, one possible reason for the underdevelopment of these skills among students may be their cognitive abilities at this particular age level. As identified in the study conducted by Ateş and Bahar (2002), the skills in which students exhibited the greatest deficiencies and misconceptions were "identifying and controlling variables" and "data analysis and graphing." The same study also suggests that the linguistic structure has a clear impact on students' difficulty in understanding the terms dependent variable, independent variable, and controlled variable. In another study by Ateş (2005), it is stated that third-year elementary education students were unable to distinguish between dependent and independent variables due to their incomplete understanding of the relevant concepts in variable identification and control.

It can be stated that the findings of this study conducted with sixth-grade middle school students are similar to those of the study by Temiz and Tan (2009) involving ninth-grade students. At both educational levels, students were observed to exhibit deficiencies in these fundamental scientific process skills and to face certain difficulties. Both middle and high school students experience conceptual difficulties in identifying variables. In particular, students encounter difficulties in accurately defining and distinguishing between dependent, independent, and controlled variables.

Finally, students' attitudes toward science directly affect their learning processes. Students who exhibit a positive attitude toward science tend to be more active in class and more open to learning new concepts. In their study, Yenice et al. (2012) reported that as students' motivation toward science increased, their interest in science courses and their academic achievement in science also improved. Altınok (2004) found that students' attitudes toward science influence their achievement motivation, and that negative attitudes toward science may hinder this motivation. In a study examining the effects of anxiety and evaluation threat on students' achievement and motivation, Hancock (2001) showed that students experiencing anxiety demonstrated lower performance. Therefore, instructional strategies should be designed in ways that engage and motivate students in order to improve their attitudes toward science and enhance their learning motivation. All of these factors should be carefully addressed in ways that support the development of students' variable identification skills.

4.1. Limitations and Recommendations

The existence of some limitations related to this study should be taken into consideration. The first one is that the first phase of the study was conducted with a small number of participants. Especially considering the scales used in the study, this number could have been slightly higher. However, the school selected for data collection did not have a larger number of students who met the specified conditions. Another limitation is that only one of the science process skills was analysed. However, these skills are often considered as complementary and nourishing each other. Although other related skills were emphasised where necessary, the fact that this study focused only on 'determining and controlling variables' and partly on 'forming hypothesis' skills can be seen as a limitation.

Considering the limitations of this study, some suggestions can be made for future research. Firstly, the study can be repeated with secondary school students at different grade levels. In addition, it may be more effective to include more participants in the study in terms of quantitative data. Analysing scientific process skills by considering them as a whole rather than individually may be a good suggestion for future researchers.

Ethics Committee Decision

This research was carried out with the permission of Nevşehir Haci Bektaş Veli University Publication Ethics Board with the decision numbered 2022.12.351 dated 30.11.2022.

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