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Scientific article

Azim Ashirbayev[1*]

Nizami Tashkent State Pedagogical University, Tashkent, Uzbekistan

E-mail: [1]az.ashirbaev@gmail.com

Analysis of the Work of Foreign Researchers on the Prevention of Typical Errors made by Students

Abstract. The article reviews the theoretical literature on the issue of the occurrence and causes of errors in learning, identifies the types of errors. The author analyzes studies on typical errors made by students when mastering geometric problems. This article investigates how foreign researchers, including Schleppenbach and others, examine student errors in classroom settings. A key comparison is made between Chinese and American teachers, revealing different approaches: American teachers often hide or avoid discussing student mistakes, while Chinese teachers encourage students to reflect on their errors conceptually. This reflective process is essential for students to develop a deeper understanding of the material. Ball emphasizes that teachers should use mistakes as a learning tool, delving beyond simple "right or wrong" analyses. Newman's error analysis also plays a crucial role, highlighting stages where students encounter difficulties—reading, comprehension, transformation, and processing. The study also emphasizes spatial intelligence, including skills like spatial perception, mental rotation, and visualization, to assess how students solve geometric problems. Understanding the types of errors, such as procedural or encoding mistakes, is essential for improving teaching methods. Furthermore, researchers like Jacobs and Ambrose suggest that teachers can guide students to think critically about their mistakes, allowing them to correct misconceptions.

Keywords: Typical mistakes, error-prone tasks, error correction, students' thinking, student errors, conceptual learning, spatial intelligence, Teaching strategies.

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Introduction

Schleppenbach and others [1] investigated the use of errors in classroom discussion by comparing the lessons of Chinese and American teachers. They report that while American teachers tended to avoid and hide student mistakes, Chinese teachers tended to force students to think about the original question in conceptual ways. Indeed, repeating the procedure until students realize their mistakes is a well-known, typical strategy that US teachers have used when dealing with their students' mistakes in the classroom [2]. Ball emphasizes that teachers should go beyond the superficial “right or wrong" analysis of tasks. Rather, teachers should use student mistakes as a window into student understanding, aiming to help students understand the conceptual basis of their mistakes [3].

Students' mistakes in solving geometric problems are described using Newman's error analysis. The Newman procedure is a sequential step in understanding and analyzing when solving a problem. Students face various obstacles when answering tasks, namely, problems of reading, understanding, transformation, processing and coding [4]. The identification of students' mistakes is required as a guideline when choosing suitable learning models and information technology tools, based on the spatial intelligence of students on geometric material. Students are not aware of the mistakes made. In addition, students do not know where the error occurred, so they cannot conduct a reflection to correct the mistakes made. Therefore, it is necessary to conduct a study to describe the mistakes of students in solving geometric problems from students' spatial intelligence perspective [5]. In this vein, spatial intelligence is measured using indicators, including the ability to determine the vertical and horizontal direction of an object (spatial perception), the ability to see the movement or displacement of part of the configuration (visualization), the ability to determine the results of two- and three-dimensional rotation (mental rotation), to associate the configuration of an object with another object (spatial relation) and the ability to guess the image of an object at a certain angle (spatial orientation) [6].

Materials and methods

The methodological foundation of this study is based on analyzing different types of errors students make when solving geometric problems. Four main types of errors have been identified: - perception errors – occur when students struggle to interpret the problem statement and fail to distinguish essential information from irrelevant details; - transformation errors – arise when students understand the problem but cannot correctly determine the sequence of steps needed to solve it; - procedural errors – occur when students know the correct sequence of steps but make mistakes in applying the procedure; - encoding errors – appear in the final stage of solving a geometric problem, where students incorrectly record the final answer. For example, when calculating the surface area of a prism, they may miswrite the final result.

The study examines how teachers' understanding of the nature of errors affects their teaching strategies. Some researchers, such as Jacobs and Ambrose, suggest guiding students' reasoning to help them recognize and correct their mistakes. Others, like Shaughnessy, focus on fostering students' critical thinking, emphasizing that analyzing errors promotes deeper understanding.

Additionally, the study explores common differentiation errors made by engineering students. The findings indicate that many students struggle with differentiation due to weak foundational math skills and an over-reliance on rote memorization. This highlights the need for teaching methods that address knowledge gaps.

Avoiding mistakes made by researchers

The research also considers the role of teachers in fostering a "positive error climate." According to Tulis, teachers’ support and the creation of a learning environment where mistakes are seen as a natural part of education significantly enhance student learning.

Research shows that one of the most common types of errors is the so-called "perception errors", which arise due to the fact that students do not have the ability to interpret questions and apply question processing strategies. With this error, the error most often occurs when choosing information, and it is difficult for students to distinguish between relevant and irrelevant information within the task [7]. Another fairly common type of error is the "transformation error", which occurs when the student understands the essence of the problem, but cannot determine the sequence of operations necessary to solve the problem [8]. There are also procedural errors that occur when a student can determine the sequence of operations necessary to solve a problem, but makes a mistake when applying the procedure [9]. And finally, an encoding error is the last type of error that needs to be identified. This error manifests itself in the last stage of solving a geometric problem, in which students incorrectly complete the final answer. For example, when students have to determine the surface area of a prism, with a known base length and height of the prism, they incorrectly indicate the final answer, making mistakes when calculating the final result [10].

In cases where a student made a mistake or came to the wrong answer, teachers' understanding of the basics of mistakes is necessary for the purposes of learning, which is related to the current understanding of students [11]. Some may approach the interaction with the student around the wrong answer in order to help the student correct the mistake [12]. For example, Jacobs and Ambrose describe a set of deliberate actions to support a student's mathematical reasoning. On the contrary, others focused on developing students' thinking. As such, Megan Shaughnessy and others in their work discussed the skills and abilities of teachers to encourage students to think when a student has the wrong answer. In this case, if the student's thinking is sufficiently probed, the student is able to recognize the mistake and reconsider his/her work [13].

Another study presents the results of an analysis of typical (common) differentiation errors made by electrical engineering students. Possible reasons that led to common mistakes and misconceptions among students when solving tasks were identified. The results showed that students often made mistakes when solving the main derivative formula. Some of them incorrectly differentiated functions, while others could not remember the derivative of the base function. Based on this, it was concluded that the errors could have been caused by their previous poor knowledge of the basics of mathematics and excessive focus on specific mathematical rules. Thus, this study revealed the causes of errors related to the quality of previous education or with their tendency to only memorize mathematical formulas [14]; at the same time, it is not known what role external factors contribute to students making those mistakes, for example, gaps in educational materials or intentional traps in assignments. Berger and Brodie argue that typical mistakes empower teachers, because such mistakes give them the opportunity to figure them out without blaming students and themselves [15]." This approach also contributes to the creation of a favorable (positive) learning environment. Maria Tulis in her work notes that teachers should be sensitive to students' mistakes and should create a positive climate of mistakes, which is determined by the quality of everyday classroom experience in situations of mistakes. By "positive climate" she means a learning environment with a positive culture of mistakes, in which students are able to recognize their misconceptions and, consequently, initiate learning processes. On the contrary, a negative error management culture, which usually excludes communication and error correction, occurs when students suspect that their mistakes are evaluated negatively, or when students expect mistakes to be explained by a lack of skills [16].

Kornell and others conducted a study that directly compared the effect of creating and not having an error. They compared a condition in which the answer or goal was simply given to participants without intermediate error generation (no error condition) with a condition in which participants were asked to guess the answer first before giving the correct answer (error generation condition). The experiment was carefully controlled to ensure that the amount of time spent learning the correct answer was the same under different conditions. Kornell and his colleagues also excluded from consideration any cases when a person did not create an error in the error generation condition. The study revealed that in the final test, participants were significantly better at remembering correct answers when they made a mistake than when they didn't. Thus, it seems that error generation is not necessarily bad, and that it should be avoided at all costs. In reality, error generation seems to promote learning [17].

Discussion

The discussion of the findings highlights several key aspects that influence the learning process and students' ability to analyze their mistakes independently. One of the significant results confirms the hypothesis that creating conditions for error reflection positively impacts education. A study conducted by Kornell and colleagues found that students remember correct answers better when they first make a mistake than when they receive the correct answer immediately. This suggests that errors are not always negative but can actively contribute to learning.

The role of teaching strategies is crucial. As noted by Berger and Brodie, analyzing typical mistakes can be a tool for improving educational methodologies. Understanding the nature of errors allows teachers not only to correct them but also to predict potential difficulties students may face. Meanwhile, Tulis' research highlights that the perception of mistakes in the classroom can shape either a positive or negative learning climate. In the former case, mistakes are seen as a natural part of learning, while in the latter, they are viewed as indicators of a lack of knowledge, which can demotivate students.

Finally, the literature review indicates that improving education quality requires considering students' spatial intelligence. Mental object manipulation, visualization, and spatial relationships play a crucial role in understanding geometry. This is supported by studies from Maier and Riastutti, which demonstrate that spatial intelligence levels directly affect students' ability to solve geometric problems.

Thus, the analysis suggests the need to revise teaching methodologies, integrate error reflection practices, and develop students' spatial thinking.

Conclusion

There is a broad consensus that it is important for teachers to be familiar with their students' ways of thinking about mathematical concepts, both right and wrong. The study of possible causes of common (typical) mistakes and misconceptions of students can contribute to the expansion of knowledge and skills of teachers. The presence of typical errors can create an opportunity for the use of surveys and personal interviews with students to identify their general tendency of thinking (and) or external causes of errors, which, in turn, will play a positive role in improving the knowledge, tools and educational approaches of teachers, and possibly also for revising the whole learning system [18].

Recognizing and analyzing student mistakes can enhance teaching strategies. Creating a positive learning environment where mistakes are viewed as learning opportunities, as suggested by Berger and Brodie, improves student engagement and understanding. Mistakes offer insights into student thinking and help teachers adjust their approaches for better learning outcomes.

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Азим Аширбаев

Низами атындағы Ташкент мемлекеттік педагогикалық университеті,
Ташкент, Өзбекстан

Шетелдік зерттеушілердің студенттердің жіберген қателіктерін болдырмау жөніндегі жұмыстарын талдау

Аңдатпа: Мақалада оқу барысында қателіктердің пайда болуы мен себептері туралы теориялық әдебиеттер қарастырылады және қателіктердің түрлері анықталады. Автор студенттердің геометриялық есептерді меңгеру кезіндегі жіберетін типтік қателіктеріне арналған зерттеулерді талдайды. Мақалада сондай-ақ Шлеппенбах және басқалары сияқты шетелдік зерттеушілердің оқушылардың сыныптағы қателіктерін қалай зерттейтіні талданады. Негізгі салыстыру қытайлық және американдық мұғалімдер арасында жүргізіліп, әртүрлі тәсілдер анықталады: америкалық мұғалімдер көбінесе студенттердің қателіктерін жасырып, оларды талқылаудан аулақ болады, ал қытайлық мұғалімдер студенттерді қателіктерін ұғымдық тұрғыдан ойлауға ынталандырады. Бұл рефлексивті процесс студенттерге материалды тереңірек түсіну үшін өте маңызды. Балл мұғалімдер қателіктерді тек "дұрыс немесе қате" деген талдаудан тыс оқу құралы ретінде пайдалануы керек деп баса айтады. Ньюманның қателіктерді талдауы да маңызды рөл атқарады, өйткені ол студенттердің оқу процесінде қиындықтарға тап болатын кезеңдерін (оқу, түсіну, түрлендіру және өңдеу) атап көрсетеді. Зерттеу сонымен қатар кеңістіктік интеллектке, оның ішінде кеңістіктік қабылдау, ойша айналдыру және визуализация сияқты дағдыларға назар аударады, студенттердің геометриялық есептерді қалай шешетінін бағалауға мүмкіндік береді. Процедуралық немесе кодтау қателіктері сияқты қателіктердің түрлерін түсіну оқыту әдістерін жақсарту үшін маңызды. Сонымен қатар, Джейкобс және Амброуз сияқты зерттеушілер мұғалімдер студенттерге қателіктерін сын тұрғысынан ойлауға көмектесу керек деп ұсынады, бұл олардың қате түсініктерін түзетуге мүмкіндік береді.

Түйін сөздер: типтік қателіктер, қателікке бейім тапсырмалар, қателіктерді түзету, студенттердің ойлауы, студенттердің қателіктері, ұғымдық оқыту, кеңістіктік интеллект, оқыту стратегиялары.

Азим Аширбаев

Ташкентский государственный педагогический университет имени Низами, Ташкент, Узбекистан

Анализ работ зарубежных исследователей по предотвращению типичных ошибок, совершаемых студентами

Аннотация: В статье произведен обзор теоретической литературы по вопросу возникновения и причин ошибок в обучении, определены разновидности ошибок. Автором проанализированы исследования о типичных ошибках, допускаемые студентами при освоении геометрических задач. Основное сравнение проводится между китайскими и американскими преподавателями, выявляя различные подходы: американские преподаватели часто избегают обсуждения ошибок

студентов или скрывают их, в то время как китайские преподаватели побуждают студентов размышлять о своих ошибках концептуально. Этот рефлексивный процесс является ключевым для того, чтобы студенты глубже понимали материал. Балл подчеркивает, что преподаватели должны использовать ошибки как инструмент обучения, выходя за пределы простой дихотомии "правильно или неправильно". Анализ ошибок Ньюмана также играет важную роль, выделяя этапы, на которых студенты сталкиваются с трудностями — чтение, понимание, преобразование и обработка. В исследовании также подчеркивается значение пространственного интеллекта, включая навыки пространственного восприятия, ментальной ротации и визуализации, для оценки того, как студенты решают геометрические задачи. Понимание типов ошибок, таких как процедурные или кодировочные, имеет важное значение для улучшения методов обучения. Более того, исследователи, такие как Джейкобс и Амброуз, предлагают, чтобы преподаватели помогали студентам критически осмысливать свои ошибки, что позволяет им исправлять заблуждения.

Ключевые слова: типичные ошибки, задачи, подверженные ошибкам, коррекция ошибок, мышление студентов, ошибки студентов, концептуальное обучение, пространственный интеллект, стратегии преподавания.

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Авторлар туралы мәліметтер:
Аширбаев Азим Азатович – хат-хабар авторы, педагогика ғылымдарының кандидаты, доцент, Низами атындағы Ташкент мемлекеттік педагогикалық институты, Бунедкор көшесі, 27 үй, Ташкент, Өзбекстан.

Сведения об авторах:
Аширбаев Азим Азатович – автор для корреспонденции, кандидат педагогических наук, доцент, Ташкентский государственный педагогический университет имени Низами, ул. Бунёдкор, д. 27, Ташкент, Узбекистан.

Information about authors:
Ashirbayev Azim Azatovich – corresponding author, candidate of Pedagogical Sciences, Associate Professor, Nizami Tashkent State Pedagogical University, Bunyodkor str., 27, Tashkent, Uzbekistan.