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# Exploring Student Errors in Solving Derivative Problems: A Systematic Literature Review

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**Abstract:** Derivative material is essential in developing students' critical thinking skills and its application in various scientific fields, specifically in mathematics. However, numerous studies revealed that many students still considered this material difficult, which often causes students to make mistakes in solving derivative problems. This study aims to analyze students' errors in solving derivative problems. This research method used systematic literature review with data synthesis process, qualitative data analysis through thematic analysis, and PRISMA method for data selection which obtained 10 articles from 232 articles on the Google Scholar, Semantic Scholar, and Scopus pages. The analysis results showed uneven fluctuations in the number of studies, peaking in 2022. The distribution of research covers nine provinces in Indonesia, with a dominance in the NTB province, although the distribution is still uneven. Newman's theory became the primary approach to analyzing student errors. Most of the research was published in SINTA 4 and SINTA 5 journals, while contributions in highly reputable journals are still minimal. The most dominant student error occurred at the encoding/looking back stage, which was caused by a lack of understanding of the derivative concept, inaccuracy, rushing, and lack of habit to re-examine the work. Other errors include conceptual, procedural, and technical errors related to derivative facts, concepts, operations, and principles. As a solution, interactive teaching materials based on the Newman procedure was recommended to improve students' understanding of derivative concepts.

**Keywords:** derivative, mathematics, student errors, systematic literature review.

## ▪ INTRODUCTION

Mathematics has an essential role in developing students' critical thinking skills. This ability provides a strong foundation for students to understand and master mathematics at various levels of education (Angco, 2021). One of the main topics taught at the Senior High School level is calculus, which includes limit function, derivative function, and integral. Based on research by Pomalato et al. (2020), calculus is one of the materials considered difficult by students because it is abstract, and it is difficult to find its application in real life. This is not in line with the statement that students' understanding of mathematics serves as a provision to solve problems that occur in everyday life (Pati et al., 2024). In addition, advanced mathematical understanding, such as calculus material, has broad applications in various scientific fields such as physics, chemistry, biology, economics, and engineering (Al-Agili et al., 2012). Other research also reveals that the material of function derivatives serves as a basis in advanced mathematics and has wide applications in various scientific fields, such as physics, economics, and engineering (Fathurrohman & Sugandi, 2023; Handayani & Kusnandi, 2023). For example, according to Feudel & Biehler (2021), derivative material is not only a fundamental mathematical concept but also has practical applications in analyzing changes in economic decision-making production. Given the importance of this material,

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an in-depth analysis of students' ability to understand derivatives is needed to improve learning effectiveness.

Some studies show that students' ability to solve problems related to function derivatives is still low (Mutia et al., 2023). According to Quezada (2020) Many students still have difficulty solving derivative problems, which results in students often making various mistakes. Unidentified and unaddressed errors can cause students' understanding to become shallow, ultimately hindering their development in more complex mathematics. (Dj Pomalato et al., 2020; Hoth et al., 2022; Tasman et al., 2018). Tiwari and Fatima (2019) revealed that student errors allow teachers to analyze the cognitive level of students so that they can develop learning plans according to student needs. Therefore, strategic efforts are needed to identify the types of errors that students often make and understand the factors that cause them so that appropriate solutions can be formulated to improve their understanding.

Various error analysis theories can be used to observe the types and causes of errors students make. One popular theory is Newman's theory, which focuses on the five stages of mathematical problem-solving: reading, understanding, transformation, process skills, and encoding (Clements, 1980; Mubarokah & Amir, 2024; Singh et al., 2010; Triliana & Asih, 2019). In addition, Polya's theory is also often used, which includes four stages: understanding the problem, planning the solution, executing the plan, and re-examining the results. (Fahrudin et al., 2019; Nguyen et al., 2023). This approach helps to analyze student errors in the context of a more systematic problem-solving strategy. On the other hand, Kastolan's theory offers a more detailed approach by dividing student errors into conceptual, procedural, and technical errors (Esterlina & Dahlan, 2023; Yarman et al., 2020). Although many researchers have conducted research analyzing student errors in derivative material, no research has comprehensively examined these errors.

This research aims to fill this gap through a systematic literature review, according to Siddaway et al. (2019) Systematic Literature Review (SLR) is a research method that aims to comprehensively find and synthesize research that refers to specific questions. This method uses organized, transparent procedures and can be replicated at every stage (Juandi & Tamur, 2021). By reviewing relevant research, this study will identify the types of errors that students often make, the factors behind them, and recommendations that can be used to minimize the occurrence of these errors. The findings of this study are expected to make theoretical and practical contributions to improving the quality of mathematics learning, especially on the material of function derivatives.

Based on the description previously described, this study will answer three main questions, namely: (1) how is the description of student error analysis research on derivative material reviewed based on the year, article source, and error theory used in the 2014-2024 range; (2) what are the types of errors that students often make in solving function derivative problems; and (3) what are the factors that cause these errors.

## ▪ METHOD

### Research Design

This study is SLR, which focuses on studies that discuss the analysis of student errors in the material of function derivatives. A properly conducted systematic review provides strong evidence to support the application of research results in mathematics education (Purssell & McCrae, 2020). The results of this review are expected to give a clear picture of student errors in solving function derivative problems so that it can be used as a basis for designing effective learning strategies to improve student understanding of this material.

**Research Strategy**

This research is using relevant keywords, such as "student error analysis" and "function derivatives" to ensure that the articles found were related to the research topic. The search was conducted through several widely recognized databases: Google Scholar, Semantic Scholar, and SCOPUS. Only articles published in journals indexed by SINTA and SCOPUS were selected for further review to ensure the quality and validity of the research results. As stated by Mahaliyanaarachchi (2016), indexed journals are generally regarded as having superior scientific standards compared to those that do not, as indexing databases only include journals that have undergone a thorough and rigorous review process.

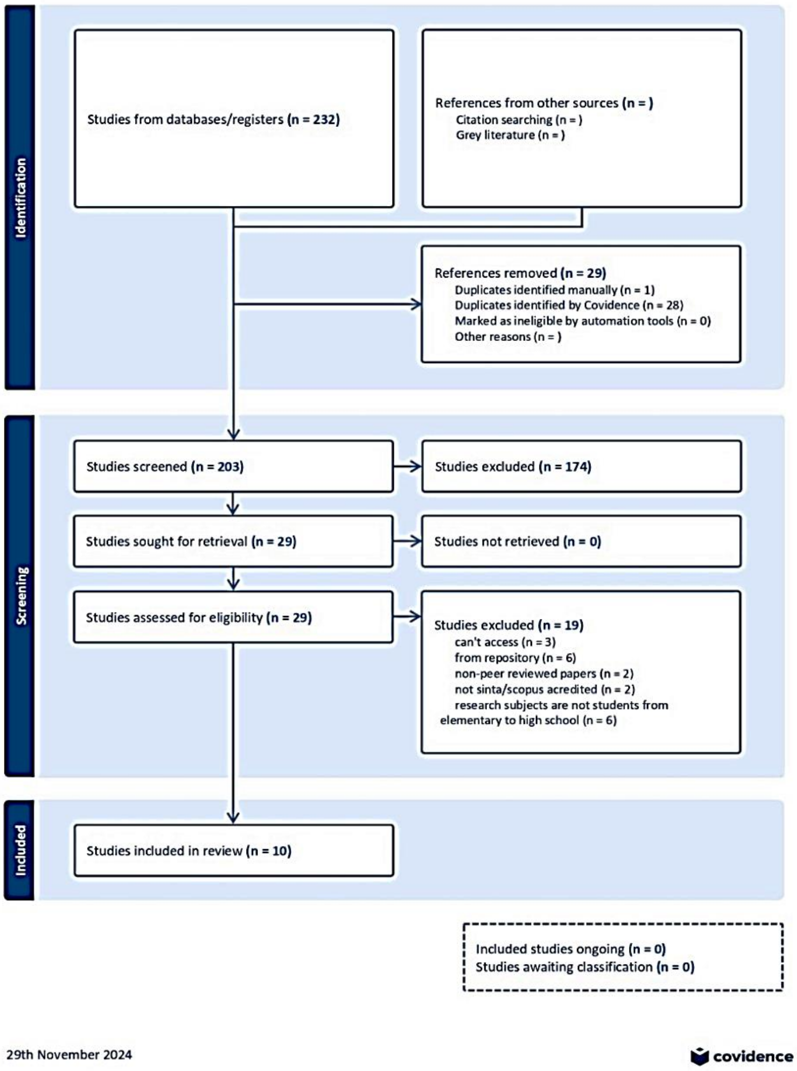


**Figure 1**. Search strategy using PRISMA

The screening process was carried out in stages to obtain results per the research context. At the initial stage, 232 articles were identified through a search using predetermined keywords, then further filtered based on inclusion and exclusion criteria so that at the end of the screening stage, 10 articles were successfully included in this systematic review after passing all the screening stages based on the PRISMA stages described in Figure 1.

This diagram shows the study selection flow to ensure that only quality and relevant studies are included in the review. The PRISMA stages in SLR include identification, screening, eligibility, and article selection to ensure the study selection process is systematic, transparent, and bias-free, thereby increasing the validity and trustworthiness of the research results.

## Inclusion and Exclusion Criteria

This study's population includes all research on analyzing student errors in solving derivative problems. The sample was carefully selected based on the predetermined inclusion criteria, which are described in Table 1 below.

**Table 1.** Inclusion criteria

| Inclusion Criteria | Reason |
|---|---|
| Articles relevant to the topic of student error analysis on derivative material | This research focuses on identifying students' error patterns in understanding and solving function derivative problems. |
| Research published between 2014-2024 | This period was chosen to ensure that the data analyzed reflected current findings and approaches in mathematics education. |
| The research subjects are high school students in Indonesia | Derivative material is generally taught at the high school level according to the mathematics education curriculum in Indonesia. |
| Articles published in SINTA or SCOPUS-indexed journals | SINTA or SCOPUS-indexed journals have high quality and accuracy standards in the publication process, including rigorous peer review |
| Articles in Indonesian and English | Indonesian was chosen to support the diversity of local literature and the relevance of the educational context in Indonesia, while English was selected to broaden the scope of international literature. |

Articles that did not meet the inclusion criteria were included in the exclusion criteria, namely (1) articles that were not relevant to the topic of analyzing student errors on derivative material; (2) research conducted other than the 2014-2024 range; (3) research subjects who were not high school students; (4) articles that SINTA or SCOPUS did not index; and (5) articles that were not written in Indonesian or English.

## Data Analysis

A descriptive qualitative data analysis approach was used to interpret the results of the selected studies. The analysis process was conducted through four main stages. First, each article was read and understood thoroughly to gain an in-depth understanding of the findings and their relevance to the research. Second, the main findings from each study were summarized, focusing on what errors students make in solving derivative problems.

Third, the findings were compared to identify the most common errors, trends, or gaps between the studies. Finally, the researcher draws a comprehensive conclusion based on the synthesis of findings, which includes identifying areas that require further research and potential practical applications in education.

## ▪ RESULT AND DISSCUSSION

There are three main research questions: (1) How is the description of student error analysis research on derivative material reviewed based on the year, article source, and error theory used in the 2014-2024 range? (2) What types of errors do students often make in solving function derivative problems? (3) What are the factors that cause these errors? The following is explained in more detail based on each research question.

**RQ1: How is the description of student error analysis research on derivative material reviewed based on the year, article source, and error theory used in 2014-2024?**

Based on the literature review analysis results, 10 articles related to the analysis of student errors in solving derivative problems were identified. These articles were then categorized based on the year of research, research location, error analysis theory used, and journal indexation. Figure 2 below shows the number of studies conducted between 2014 and 2024.

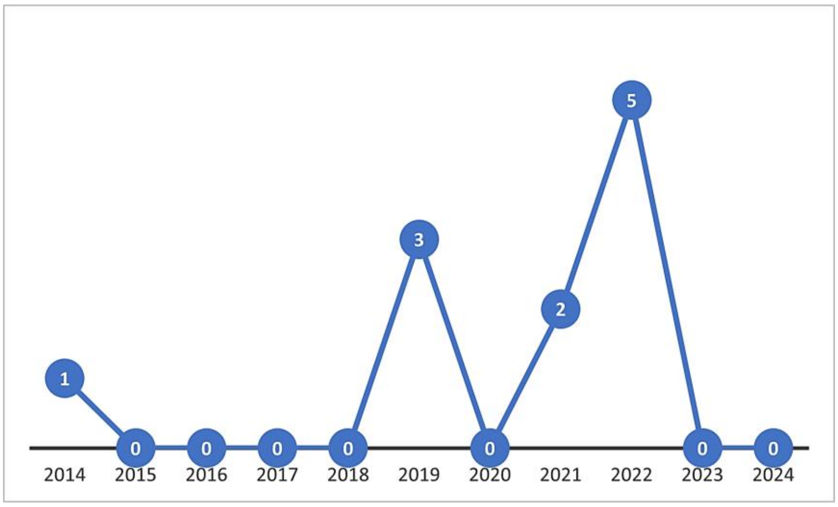


**Figure 2**. Year of publication

Figure 2 above shows that the number of studies conducted each year fluctuates, with patterns that tend to be uneven. 2014 there was one research, but in the following years (2015 to 2018), no related research was found. The number of studies began to increase again in 2019, with three studies, followed by a decrease in 2020, when no studies were identified.

In 2021, the number of studies increased to 2 and peaked in 2022 with five studies, making it the year with the most significant contribution in this data. However, in 2023 and 2024, no relevant research was found again. Overall, the research trend on this topic shows a significant increase in 2022, but the data shows a consistently low number of studies from year to year. This may reflect a lack of attention or prioritization of this topic in specific periods.

After looking at research trends by year, it is also essential to understand the geographical distribution of research locations conducted. This distribution provides an overview of the regions in Indonesia that have contributed to research related to student error analysis on the derivative of functions and identifying regions that may still be underrepresented in this study. More details on the geographical distribution of the research are shown in Figure 3 below, which provides a visual illustration of the locations of related research in various regions of Indonesia.

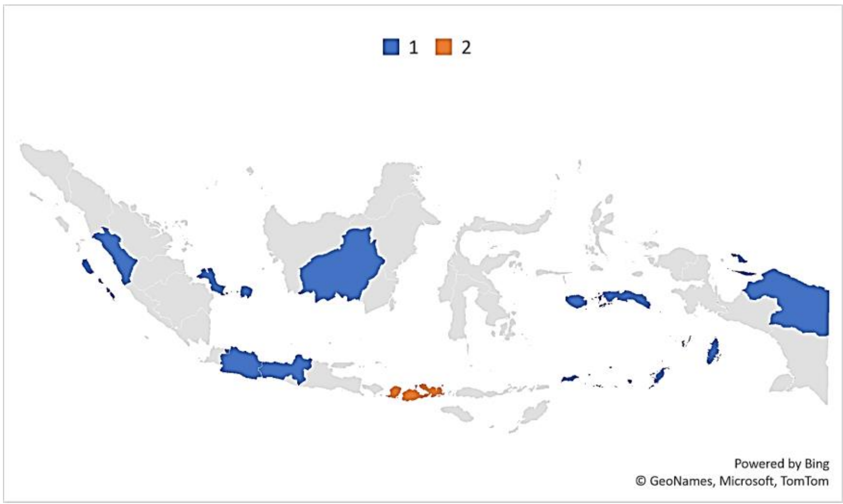


**Figure 3**. Research location

The data shows the distribution of research locations related to student error analysis on derivative material in various regions of Indonesia. Based on this data, it can be seen that the studies are spread across nine provinces, with a relatively even proportion. NTB recorded the highest number of studies, namely two studies. At the same time, other provinces, such as Papua, Central Java, Bangka Belitung, Jakarta, Central Kalimantan, Maluku, West Java, and West Sumatra, only had 1 study each. This suggests that the topic is not evenly distributed across Indonesia, with dominance in specific regions and underrepresentation in others.

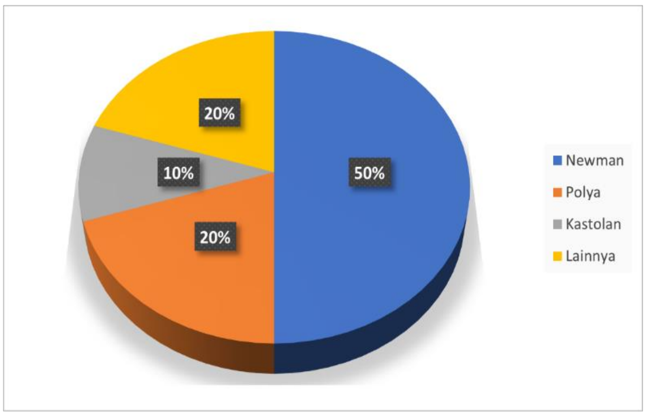


**Figure 4**. Errors analysis theory

In terms of error analysis theory, Figure 4 above shows that Newman's theory is the most widely used in this study, with as many as five articles referring to it because of its ability to systematically identify the stages of student errors. Polya's theory was used in 2 studies, focusing on solving mathematical problems, while Kastolan's theory was only used in 1 study. In addition to these three error theories, two other studies used error analysis indicators created by the researchers themselves. This shows a variety of approaches to analyzing student errors on the material of function derivatives.

Finally, the results of the studies of student error analysis on derivative material, when viewed from the indexation of journals, are explained in Figure 5 below. Analysis of the journal index provides an overview of the credibility and level of recognition of research in the academic environment.

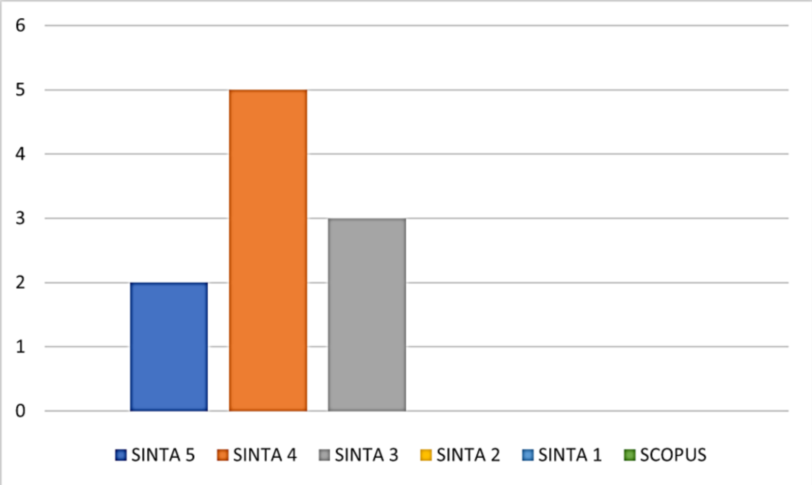


**Figure 5**. Indexing journal

The data shows the journal's accreditation level and the source of research related to student error analysis on derivative material. Five articles were published in SINTA 4 indexed journals, followed by three articles in SINTA 3 journals and two articles in SINTA 5 journals. No research was found in SINTA 2, SINTA 1, or SCOPUS-indexed journals.

This shows that research on this topic is mainly published in journals with medium to low accreditation levels, while contributions from highly reputable or international journals are still not found. This finding indicates the need to improve the quality of research to be published in journals with higher accreditation.

**RQ2: What types of errors do students often make in solving function derivative problems?**

The research data results in this literature review are a summary analysis of ten articles related to student errors in solving derivative problems in terms of various error theories, such as Newman's theory, and theories other than Newman (such as Polya, Kastolan, etc.). The research data is presented in Table 2.

**Table 2**. Research findings of student errors on derivative problem in review of newman's theory

| Code | Authors | Research Results |
|---|---|---|
| N1 | Fitri, N. W., Subarinah, S., & Turmuzi, M. (2019) | Reading errors are very low, comprehension and transformation errors are moderate, process skill errors are low, and encoding errors are very high. |
| N2 | Anugrah, T. M., & Kusmayadi, M. A. (2019) | The most common error students make is errors in understanding the problem. |
| N3 | Meiliasari, Wijayanti, D. A., & Azima, L. A. (2021) | Students made all types of Newman errors when solving derivative application problems. |
| N4 | Belnard, I., Moma, L., & Laamena, C. (2022) | Students made errors in understanding the problem, transformation, process skills, and encoding. |
| N5 | Khotimah, H., Amrullah, Tyaningsih, R. Y., & Sridana, N. (2022) | The highest error made was the error in writing the final answer. |

According to Table 2, comprehension and encoding errors are generally the most common types of errors made by students, as the results of research conducted by Kurniati et al. (2021) also reveal the same thing. Raduan also reinforces this (2010) and Clarkson (1991) which revealed that comprehension errors that occur when working on math problems have been identified as one of the most frequent categories in error analysis. In N1, the results showed that reading errors were in very low criteria, with a percentage of 23%. Errors in understanding the problem and transformation are in moderate criteria with percentages of 44% and 49%, respectively. Process skill errors were among the low criteria, with a rate of 29%. Answer writing errors are in very high criteria with a percentage of 78%. Research conducted by N5 in terms of gender revealed that the highest errors in male and female students occurred at the encoding errors stage, with a higher percentage in women (72%) than men (63%).

**Table 3.** Research findings of student errors on derivative problem in review of other theories

| Code | Authors | Research Results |
|---|---|---|
| R1 | Sawitto, A. N., Hadiyanti, Y. R., & Tandililing, P. (2014) | Based on Polya's stages, students made errors in understanding the problem, devising a plan, carrying out the plan, and looking back. |
| R2 | Apriliyanto, B. (2019) | Based on Polya's stages, students made 7.5% of errors at the understanding stage, 12.5% at the planning stage, 55% at the problem-solving stage, and 100% at the rechecking stage. |
| R3 | Wahyuni, N. T., Aima, Z., & Fitri, D. Y. (2022) | According to Kastolan, students make three types of errors: conceptual errors, procedural errors, and technical errors. |
| R4 | Pinardi, J., Suparman, Subagjo, A., & Punding, W. (2021) | Students make errors in understanding facts, errors in understanding concepts, errors in performing operations, and errors in understanding principles. |
| R5 | Nisa, A. K., & Imami, A. I. (2022) | There are still students who make conceptual errors and calculation errors. |

Based on Table 3 above, R1 and R2 used Polya's theory in analyzing student errors through four stages of problem-solving (Polya, 2004): understanding the problem, devising a plan, carrying out the plan, and looking back. In R1, some subjects were too sure of their answers, so they did not recheck them, which ultimately led to errors in their answers. Whereas in R2 all students made mistakes at the looking back stage. On the other hand, R3 research used error analysis according to Kastolan's theory, which consists of conceptual, procedural, and technical errors. (Hamidah & Kusuma, 2024)The research found that students made all three types of errors in solving derivative problems. In R4 and R5, students often make conceptual errors and calculations.

**RQ3: What are the factors that cause these errors?**

Encoding errors occur when students complete a math task correctly but are unable to present the answer in an appropriate written form (Singh et al., 2010)Students are not accustomed to checking their answers, which causes them to make many of these mistakes. In addition, the errors made by students in Table 2 are caused by their lack of mastery of the concept of derivative material, their carelessness in answering questions, their haste in solving problems, their problem models being different from those exemplified by the teacher, and their lack of basic skills.

The factors causing the errors made by students in Table 3 are the lack of accuracy of students in answering questions, not understanding the relationship between the information given and the problem, not understanding the concept of derivatives in-depth, or not remembering the derivative formula used when answering questions, students cannot perform calculations and write variables or constants correctly, and lack of ability to describe material or apply material that has been learned.

## ▪ CONCLUSION

Research on analyzing students' errors in solving derivative problems during 2014-2024 shows uneven fluctuations, with a peak in 2022. The distribution of this research covers nine provinces in Indonesia, with dominance in NTB, but the distribution is not evenly distributed throughout the region. In analyzing student errors, Newman's theory is the most frequently used approach, while other theories, such as Polya, Kastolan, and researcher-made indicators, are only used in limited numbers. The publication of this research is mainly found in SINTA 4 and SINTA 5 journals. In contrast, contributions in highly reputable or international journals are minimal, so efforts are needed to improve the quality of research on this topic.

Regarding Newman and Polya error analysis, students still make many errors at all stages. The most dominant type of error students make is the error in encoding errors/looking back stage. The main factors causing this error include a lack of understanding of the derivative concept, inaccuracy, rushing, and lack of student habits in rechecking answers. In addition, student errors also include conceptual, procedural, and technical errors, which are influenced by a lack of understanding of derivative facts, concepts, operations, and principles, as well as the inability to remember formulas or apply material that has been learned. The alternative solution is to design interactive teaching materials based on the Newman stages that focus on understanding the concept of derivatives, exercises to improve accuracy and procedural skills, and explicit stages to familiarize students with rechecking answers.

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