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PROFILE OF STUDENTS' MATHEMATICAL LITERACY IN THE PYTHAGOREAN THEOREM BASED ON RASCH ANALYSIS

Linca Rotua Nian Sitompul*[1], Syamsir Sainuddin[2], Ranisa Junita[3]
[1,2,3]*Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Jambi, Jambi, Indonesia*

* Corresponding Author: lincasitompul3@gmail.com

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ABSTRACT

This study aims to describe students' mathematical literacy in the topic of the Pythagorean Theorem using the Rasch model analysis. The study focuses on identifying the difficulty levels of seven mathematical literacy indicators and mapping students' abilities across these indicators. A quantitative descriptive approach with diagnostic analysis was employed. The participants consisted of twenty-two ninth-grade students from a junior secondary school in Jambi City, selected through incidental sampling. The instrument was a single open-ended problem developed based on seven mathematical literacy indicators. Data were analyzed using the Rasch model, focusing on the person summary, item difficulty, reliability, and the Wright map. The results indicate that students' abilities were generally below the item difficulty level. In addition, the person reliability value (0.50) and separation index (1.00) show that differences in students' ability levels were not yet clearly distinguished. Variation in item difficulty shows that representation, the use of mathematical tools, and symbolic language were relatively easier, while communication, problem-solving strategies, and reasoning were more difficult. These findings indicate a gap between students' abilities and the demands of the indicators, particularly in modeling, explanation, and reasoning.

INTRODUCTION

Mathematical literacy is an essential competency for students to face the challenges of the twenty-first century (Elisya et al., 2024). The Organization for Economic Co-operation and Development (OECD), through its Program for International Student Assessment (PISA), defines mathematical literacy as an individual's ability to formulate, apply, and interpret mathematics to solve problems in a variety of real-life contexts (OECD, 2023). These processes involve several competencies, namely communication, mathematization, representation, reasoning and argument, devising strategies for solving problems, the use of symbolic language and operations, and the use of mathematical tools. In this study, these seven competencies serve as indicators of mathematical literacy. Accordingly, mathematical literacy extends beyond conceptual understanding to the ability to apply mathematics functionally in everyday life.

The importance of mathematical literacy is evident from the results of the PISA assessment, conducted in various participating countries, including Indonesia. PISA is recognized as a credible international assessment for describing the quality of education and is widely used as a basis for evaluating national education systems (Hewi & Shaleh, 2020; Ismawati et al., 2023). However, the results indicate that Indonesia's performance in mathematics remains below the OECD average. In 2022, Indonesia's average score in mathematics was 366, compared to the OECD average of 472 (OECD, 2023). These findings indicate that Indonesian students' mathematical literacy remains relatively low (Putra, 2025). Consistent with this, Husni and Herman (2024) and Prastyo (2020) found that students experience difficulties in solving problems that require reasoning, modeling, and interpretation in non-routine contexts.

The Pythagorean Theorem is a mathematical topic closely related to reasoning, representation, and contextual problem solving. This topic is fundamental in junior secondary mathematics because it supports the understanding of distance, measurement, geometry, and spatial relationships, while also providing opportunities to examine how students apply mathematical literacy in both routine and non-routine situations. However, mathematics instruction still tends to rely heavily on routine exercises that emphasize procedural work and the memorization of formulas. In such learning environments, students become accustomed to solving problems by following predetermined steps, which limits their experience in dealing with tasks that require the integration of content, context, and processes, as emphasized in PISA (Qolbiyah & Sari, 2024; Retnawati et al., 2024). Consequently, students' ability to understand problems, represent situations in mathematical forms, and solve contextual problems remains limited. This situation further suggests that students may have insufficient opportunities to engage in tasks that require interpreting situations, constructing mathematical representations, and justifying their solutions.

In addition to instructional issues, assessment practices in schools also contribute to the limited understanding of students' mathematical literacy profiles. Assessment practices in schools tend to focus primarily on final scores, which limits their ability to provide diagnostic information about students' performance across different aspects of mathematical literacy. In addition, assessments that rely mainly on a small number of routine tasks often provide only limited information about students' actual abilities. When the tasks administered do not adequately represent different aspects of mathematical literacy, the resulting scores may be less consistent and less informative for instructional decisions. However, more in-depth analysis is needed to identify which indicators have been mastered and which remain underdeveloped, thereby providing a stronger basis for improving instructional practices (Ernawati et al., 2024).

The Rasch model offers an approach that enables measurement on an interval scale and allows both student ability and item difficulty to be mapped within a common framework (Zafrullah et al., 2023). The quality of measurement is also closely related to instrument design, including the scope of the assessed indicators, the variation in item difficulty, and the type of responses expected from students. Instruments with balanced cognitive demands are more likely to provide more accurate information for differentiating students' performance. Through such analysis, students' ability profiles can be identified in greater detail, providing more meaningful information for teachers in designing appropriate instructional interventions. Although Rasch analysis has been increasingly used in educational assessment, studies that specifically examine students' mathematical literacy profiles using indicator-level analysis of the Pythagorean Theorem topic remain limited. Therefore, there is a need to provide a more focused diagnostic description that highlights how students perform across different aspects of mathematical literacy within this topic.

Based on the identified problems, this study analyzes the profile of mathematical literacy among ninth-grade students at SMP Negeri 22 Kota Jambi on the Pythagorean Theorem using the Rasch model through the Ministep application. This study aims to identify the level of difficulty of each mathematical literacy indicator and analyze the alignment between students' abilities and the demands of these indicators, providing a comprehensive description of students' mathematical literacy profile. The results of this study are expected to contribute to theoretical discussions on mathematical literacy analysis based on the Rasch model, provide diagnostic information for teachers in understanding students' ability profiles, and serve as a basis for designing more effective instructional strategies.

METHOD

This study used a quantitative descriptive design with a diagnostic approach based on the Rasch model, using the Ministep application to map students' mathematical literacy on the topic of the Pythagorean Theorem. The Rasch model can produce interval-scale measurements and provide accurate information about students' abilities and the quality characteristics of test items (Prayoga et al., 2024). In addition, the model enables a direct comparison between students' abilities and item difficulty within a unified measurement scale, allowing a more precise interpretation of student performance. This design was selected because the study aimed not only to describe students' achievement levels, but also to identify patterns of difficulty across specific mathematical literacy indicators.

The research instrument consisted of a single open-ended problem developed based on seven mathematical literacy indicators, namely communication, mathematization, representation, reasoning and argument, devising strategies for solving problems, the use of symbolic language and operations, and the use of mathematical tools. The use of a single open-ended problem aimed to assess multiple aspects of mathematical literacy simultaneously, allowing each indicator to be observed through students' responses within a unified context rather than through separate items. The problem was designed within the context of the Pythagorean Theorem so that students' literacy performance could be examined through reasoning, representation, and contextual problem-solving within a single mathematical topic.

Before data collection, the instrument underwent content validation through expert judgment involving two Mathematics Education lecturers as validators. The validation focused on the alignment of the item with the research objectives, the representation of the seven mathematical literacy indicators, the accuracy of the mathematical concepts involved, the clarity of the language and instructions, and the appropriateness of the context used. Based on the reviewers' feedback, several revisions were made, particularly to improve the wording and contextual clarity of the item. The revised instrument was then used in the study.

Data were collected through a written test using the validated instrument during regular classroom learning activities. All students completed the test individually within the time allocated by the teacher under the supervision of the researcher and the classroom teacher. Students' written responses were then compiled for scoring and analysis using a rubric developed in accordance with the mathematical literacy indicators. The scores reflect students' performance across each aspect of mathematical literacy. The scoring was carried out analytically for each indicator. A score of 2 was assigned when the indicator was fully achieved and met the established criteria; a score of 1 indicated partial achievement or minor shortcomings; and a score of 0 was given when the student did not meet the criteria for the indicator. Thus, the maximum possible score for each student was 14 points across all seven indicators. All scores were then compiled and checked to ensure data consistency before being stored in a text format compatible with the Ministep application.

The data were subsequently analyzed using the Ministep application to estimate students' ability parameters and the difficulty level of each indicator according to Rasch model procedures, thereby providing a diagnostic description of students' abilities. Data analysis in this study focused on the key outputs of the Rasch model, namely person summary, item summary, reliability, separation index, and the Wright Map. The person summary presents key statistics used to interpret the distribution of students' abilities and to identify responses that do not fit the model. The item summary reports item measures, standard errors of estimation, and fit statistics for each indicator, enabling systematic identification of the level of difficulty and diagnostic characteristics of each item.

Person and item reliability were used to examine measurement consistency, while the separation index was used to determine the instrument's ability to distinguish different levels of student performance. Low person reliability or a small separation index indicates that the instrument does not yet clearly differentiate students' ability levels. The Wright Map visualizes the position of students' abilities relative to the difficulty level of the indicators on a common logit scale, enabling the relationship between students' ability profiles and item characteristics to be interpreted diagnostically. The results of this analysis describe students' mathematical literacy across indicators and serve as a basis for planning instructional interventions.

RESULT AND DISCUSSION

The Rasch analysis showed that most students' mathematical literacy ability was below the average item difficulty level. The results also identified differences in the difficulty of the seven indicators, with reasoning and argument, devising problem-solving strategies, and communication identified as the most challenging aspects. In contrast, representation, use of mathematical tools, and symbolic language were relatively easier. These findings were interpreted through the person summary, item summary, Wright map, and examples of students' responses, providing a more comprehensive overview of students' strengths and difficulties across different aspects of mathematical literacy.

```
     SUMMARY OF 22 MEASURED (EXTREME AND NON-EXTREME) PERSON
---
|          TOTAL                         MODEL         INFIT         OUTFIT    |
|          SCORE      COUNT     MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|------------------------------------------------------------------------------|
| MEAN       3.4        7.0       -2.33     .95                                 |
|  SEM        .4         .0         .33     .07                                 |
| P.SD       1.7         .0        1.50     .32                                 |
| S.SD       1.8         .0        1.53     .33                                 |
| MAX.       6.0        7.0       1        1.90                                 |
| MIN.        .0        7.0       -5.78     .73                                 |
|------------------------------------------------------------------------------|
| REAL RMSE    1.06 TRUE SD    1.06  SEPARATION  1.00  PERSON RELIABILITY  .50 |
|MODEL RMSE    1.00 TRUE SD    1.11  SEPARATION  1.12  PERSON RELIABILITY  .55 |
| S.E. OF PERSON MEAN = .33                                                    |
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PERSON RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .46  SEM = 1.29
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Figure 1. Person Summary

Figure 1 presents the Rasch analysis results, processed through the Ministep application for 22 students at SMP Negeri 22 Kota Jambi. The data show an average student score of 3.4 out of a maximum observed score of 6.0, while the instrument's maximum possible score was 14. The difference between the maximum score obtained in the data and the maximum possible score indicates that several mathematical literacy indicators were not fully achieved. This condition indicates that students' mathematical literacy attainment remains suboptimal, as most have not yet demonstrated mastery across all indicators. A person measuring above the average item difficulty (0.00 logits) indicates that students' ability exceeds the level of item difficulty (Supriatna et al., 2025). However, in this study, the average person's measure was −2.33 logits, indicating that students' abilities remain below the item difficulty level. Students' ability measures ranged from −5.78 to 1.0 logits. The highest standard error, 1.90, was observed among students at the upper end of the ability distribution, indicating that their ability estimates were less stable.

Person reliability refers to the consistency of the measurement of students' abilities (Arnold et al., 2018), while person separation indicates the instrument's ability to distinguish respondents across different levels of ability (Cordier et al., 2024; Yokhebed et al., 2025). A person's reliability value of 0.50 with a person separation index of 1 indicates that the instrument was not able to clearly distinguish students into different ability levels, suggesting that the variation in students' performance was relatively narrow and therefore less stable for classification into separate ability groups. The very high correlation between raw scores and measures (0.99) indicates that the raw scores were sufficiently representative of the estimated abilities. Overall, these findings provide an initial diagnostic overview indicating that students' mathematical literacy still needs improvement and can be used as a basis for improving instructional strategies.

The concentration of students at the lower end of the scale also suggests limited variation in performance, which is consistent with the low person separation index. This indicates that the instrument detected only small differences among students' ability levels, with only a few students demonstrating substantially higher performance.

```
     SUMMARY OF 7 MEASURED (NON-EXTREME) ITEM
---
|          TOTAL                          MODEL         INFIT          OUTFIT    |
|          SCORE      COUNT     MEASURE    S.E.      MNSQ   ZSTD    MNSQ   ZSTD  |
|--------------------------------------------------------------------------------|
| MEAN      10.7       22.0         .00     .51      1.02   -.31    1.02   -.35  |
|  SEM       2.9         .0         .63     .03       .25    .86     .25    .81  |
| P.SD       7.0         .0        1.55     .08       .62   2.10     .62   1.99  |
| S.SD       7.6         .0        1.68     .09       .67   2.27     .67   2.15  |
| MAX.      20.0       22.0        1.86     .64      2.13   3.04    2.13   3.02  |
| MIN.       3.0       22.0       -1.99     .43       .30  -3.28     .31  -3.23  |
|--------------------------------------------------------------------------------|
| REAL RMSE    .58 TRUE SD    1.44  SEPARATION  2.50  ITEM   RELIABILITY  .86 |
|MODEL RMSE    .52 TRUE SD    1.46  SEPARATION  2.84  ITEM   RELIABILITY  .89 |
| S.E. OF ITEM MEAN = .63                                                      |
---
ITEM RAW SCORE-TO-MEASURE CORRELATION = -1.00
Global statistics: please see Table 44.
UMEAN=.0000 USCALE=1.0000
```

Figure 2. Item Summary

The item summary analysis shows a range of item difficulty from −1.99 to 1.86 logits, with an average of 0.00 logits. Item measures represent the level of difficulty of each item (Hanim & Herdi, 2022), reflecting variation in difficulty across the indicators. Indicators with a value of −1.99 are classified as the easiest, while those with a value of 1.86 are the most difficult for students. This pattern of variation is consistent with the findings of Istiqomah et al. (2025), who reported a distribution of easy, moderate, and difficult items in a Rasch-based assessment on the Pythagorean Theorem. Similar findings were also reported by Nazharita et al. (2025), who found difficulty levels ranging from very easy to very difficult on a geometry numeracy literacy instrument. Taken together, these studies suggest that Rasch analysis can consistently capture hierarchies of difficulty across different forms of mathematics assessment. In the present study, this hierarchy provides additional insight into which mathematical literacy indicators are relatively more accessible and which remain more challenging for students.

Furthermore, separation and reliability are used to examine whether the item difficulties are consistently structured (Shaleh et al., 2025). A separation value of 2.50 and an item reliability of 0.86 indicate that differences in item difficulty across indicators are consistent, suggesting that students' abilities are not evenly distributed across all indicators. Results show that students performed better on indicators such as representation, the use of mathematical tools, and symbolic language; whereas reasoning, devising strategies, and communication were more difficult. A similar tendency was reported by Husni and Herman (2024), who found that students experienced greater difficulty on tasks requiring reasoning and interpretation than on procedural tasks. This finding suggests that students were generally more successful on indicators involving direct procedures and representations than on indicators requiring explanation, planning, and justification. This variation in item difficulty also reflects differences in the cognitive demands associated with each indicator, with items requiring interpretation and justification tend to be more challenging than those involving direct representation or symbolic manipulation. Such differences provide additional insight into how students respond to tasks with varying levels of complexity.

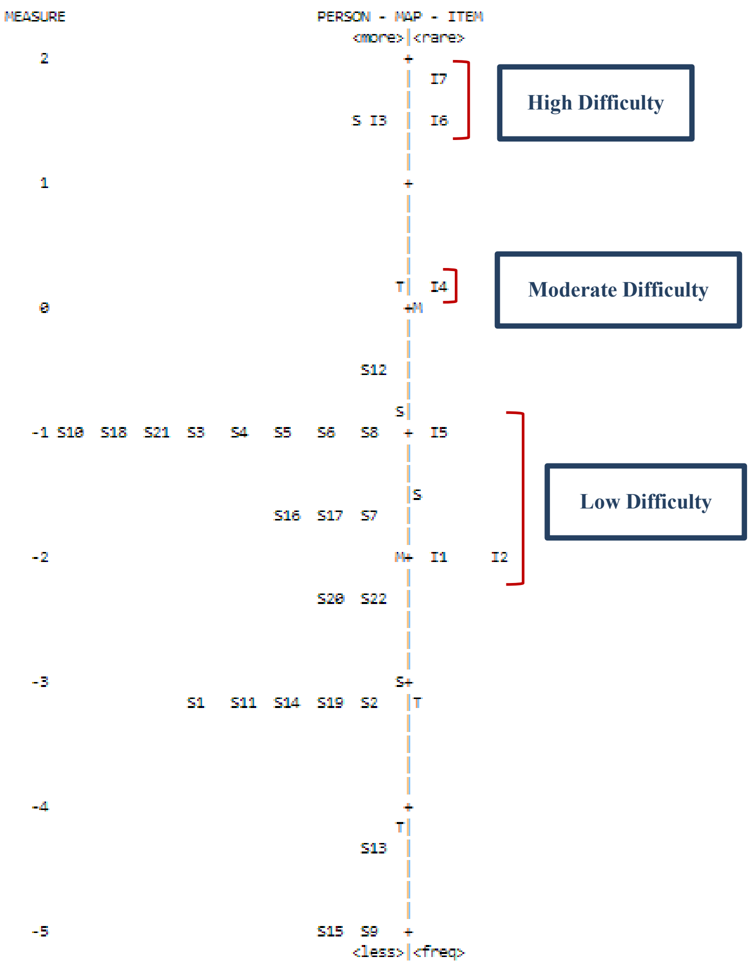
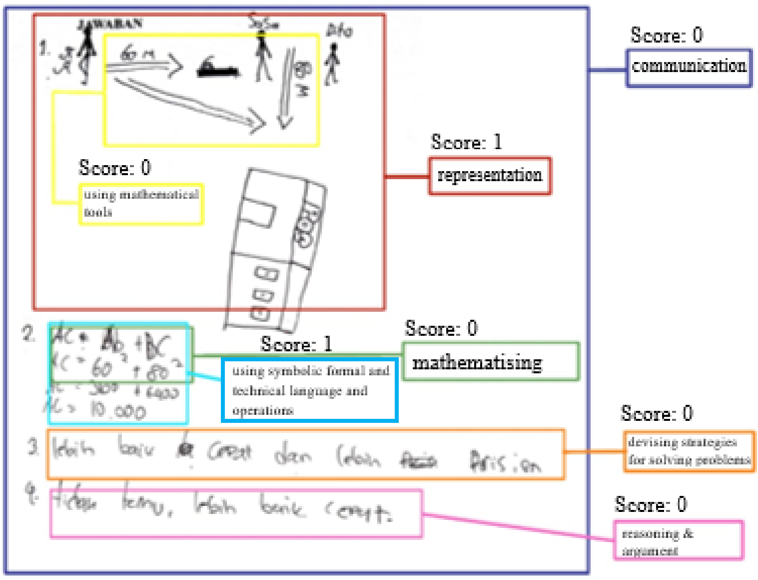


Figure 3. Wright Map

The Wright map analysis illustrates the relationship between students' abilities and the level of difficulty of the mathematical literacy items administered (Milkana Diva et al., 2025). This analysis represents each student's performance on the test items using a logit scale, where higher logit values indicate better problem-solving ability (Purnami et al., 2021). Most students are positioned below the average point of 0 logits, indicating that their mathematical literacy abilities are relatively low compared to the level of item difficulty presented.

At the upper part of the map, I7 (reasoning and argument), I6 (devising problem-solving strategies), and I3 (communication) occupy the highest logit positions and represent the most difficult indicators. This pattern can be understood from the cognitive demands of each indicator. In reasoning and argument, students are required to justify procedures, connect relevant mathematical ideas, and draw logical conclusions based on the information provided. Such demands are generally more complex than tasks that can be completed through direct calculation alone. In devising problem-solving strategies, students need to identify relevant information, determine an appropriate approach, and organize solution steps independently before carrying out computations. Meanwhile, lower performance in communication indicates that some students are still not accustomed to expressing mathematical ideas clearly, coherently, and completely in writing, particularly when responding to contextual problems. Overall, these three indicators require students not only to obtain an answer but also to explain their thinking, choose suitable strategies, and communicate their reasoning effectively.

In contrast, at the lower part of the map, I1 (representation), I2 (use of mathematical tools), and I5 (symbolic language) appear at lower logit levels, indicating that these indicators are relatively easier for most students. Meanwhile, I4 (mathematization) is located around the midpoint, representing a moderate level of difficulty. This result suggests that students tend to perform better on indicators related to representing information, using familiar procedures or tools, and applying symbolic expressions. However, the overall pattern still shows that several indicators remain above the ability level reached by most students, indicating that the alignment between students' current abilities and the hierarchy of indicator difficulty has not yet been fully achieved. These findings highlight the importance of examining students' responses in greater detail to identify specific errors and partial understanding that may not be fully captured through quantitative measures alone. Such information can serve as a basis for follow-up learning activities, especially to strengthen reasoning, communication, and independent problem-solving strategies. In classroom practice, these findings can be addressed by providing more opportunities for students to explain their reasoning, compare different solution methods, and discuss their answers with peers. The use of short contextual tasks that gradually encourage students to plan solution steps may also help develop problem-solving strategies. In addition, representations such as diagrams or sketches can be used as initial support before students move to more formal mathematical reasoning.



ENGLISH VERSION

1. Sketch showing the positions of Sasa and Dito, with directions and distances indicated.
2. $AC + AB + BC$
   $AC = 60^2 + 80^2$
   $AC = 3.600 + 6400$
   $AC = 10.000$
3. Better, faster, and more efficient.
4. Not meeting, better to be faster.

Figure 4. Student's Response

Figure 4 presents an example of a student's response, which supports the Wright map analysis by showing how students perform across each mathematical literacy indicator. Based on the scoring rubric, the student had not yet demonstrated sufficient mastery in most aspects. In the communication indicator, the student only provided part of the information from the problem without constructing a complete explanation. In terms of representation, the student attempted to illustrate the situation using a sketch and directional distances. However, the labels and positional context were not clearly defined. For the mathematization indicator, the student was unable to translate the situation into an appropriate mathematical model because there was no clear reference for determining the triangle's sides. Nevertheless, the student used formal notation and basic calculations, which shows partial achievement in the symbolic language aspect. Furthermore, in the indicators of using mathematical tools, devising problem-solving strategies, and reasoning and argument, the student did not use appropriate tools or provide relevant mathematical justification.

This pattern indicates that the student was able to begin the solution process but still experienced difficulty in organizing information, selecting an effective strategy, and explaining the reasoning behind the answer. These findings are consistent with the Wright map results, which show that most students did not achieve indicators of higher difficulty, indicating that students' main difficulties were related to indicators requiring reasoning, strategy, and mathematical communication. Overall, the findings indicate that students tended to perform better on procedural and representational indicators, while reasoning, communication, and independent strategy use remained more challenging.

CONCLUSION

The results of the Rasch model analysis, based on the person summary, item summary, Wright map, and students' response analysis, indicate that students' mathematical literacy on the Pythagorean Theorem topic has not yet aligned with the instrument's item difficulty levels. The person summary shows that the average student ability is below the average item difficulty level, while the person reliability value suggests that differences in students' ability levels have not yet been clearly distinguished. The item summary reveals a consistent variation in item difficulty, with indicators such as representation, the use of mathematical tools, and symbolic language at lower difficulty levels. In contrast, communication, devising problem-solving strategies, and reasoning are at a higher difficulty level. The findings from the Wright map and the analysis of students' responses reinforce this pattern, particularly in aspects related to constructing mathematical models, developing explanations, and providing appropriate reasoning.

Overall, these findings indicate that students require greater support in higher-order aspects of mathematical literacy, especially reasoning, communication, and strategy use. For classroom practice, teachers may use more contextual tasks, guided discussions, and opportunities for students to explain their thinking in order to strengthen these indicators. In addition, the results demonstrate that Rasch analysis can provide useful diagnostic information to identify students' strengths and difficulties; therefore, instruction can be planned more specifically according to students' needs. Future studies may involve larger samples and a wider range of mathematical topics to obtain broader evidence of students' mathematical literacy profiles.

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