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A Framework for Culturally Responsive Mathematics Pedagogy: Synergizing Alang Tulung Gayo-Based Blended PjBL and Computational Thinking

Lisa^{1,2*}, E. Elvis Napitupulu¹, Asmin¹

¹Department of Mathematics Education, Universitas Negeri Medan, Medan, Indonesia

²Department of Mathematics Education, Universitas Islam Negeri Sultanah Nahrasyiah
Lhokseumawe, Lhokseumawe, Indonesia

*lisa.iainlsm@gmail.com

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Abstract

The rapid development of digital learning in higher education often pays little attention to students' sociocultural backgrounds, causing learning technology to feel disconnected from their real experiences and values. This study developed and empirically tested an operational framework that integrates the local wisdom of *Alang Tulung Gayo* with modern learning technology to improve university students' Computational Thinking (CT) skills. Using the Plomp development model within a Research and Development (R&D) approach, the framework was implemented with 52 students enrolled in the Integral Calculus course through the Sevima EdLink platform. The model integrates cultural values such as *Mango Lo*, *Bejamu*, *Mah Atur*, *Tung Upah*, and *Berumpah-umpah* into the learning process, each reinforcing specific CT indicators. Results showed significant improvement in students' CT abilities with an N-Gain of 0.67, categorized as moderate, with Pattern Recognition achieving the highest gain (0.71). The *Berumpah-umpah* value, emphasizing deliberation and collaboration, proved especially effective in fostering abstraction and collective problem-solving. Beyond the Indonesian context, the framework highlights transferable principles of integrating local cultural values into project-based learning, offering a model that can be adapted internationally to enhance student engagement and 21st-century skills. A practical example is demonstrated through Integral Calculus projects, where students collaboratively design solutions using digital tools while applying cultural values to strengthen CT pillars. Overall, this study confirms that digital and project-based learning in higher education can be more effective and meaningful when

technological innovation is balanced with cultural values through a culturally responsive pedagogy.

Keywords: Local Wisdom Integration, Higher Education Pedagogy, Curriculum Innovation, Collaborative Learning, Problem-Solving Skills

Introduction

Technological developments in the era of the Fourth Industrial Revolution require the education system to adapt swiftly and effectively. The 21st century demands the development of more efficient, interactive, and relevant learning models, with the emergence of technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI). The rapid advancement of information technology has had a significant impact on the world of education, particularly in improving student academic performance through optimizing the teaching-learning process (Carrillo et al., 2010), and the use of technology in education can increase learning effectiveness (Kalyani, 2024).

Computational thinking is a cognitive skill that enhances critical, analytical, and systematic thinking. Computational thinking skills will also help students master 21st-century skills such as communication, collaboration, and creativity, and prepare them to face evolving digital challenges (Christensen, 2023). In contemporary education, computational thinking serves not only as a technological skill but also as an essential foundation for effective problem-solving.

Computational thinking (CT) is an alternative method for solving abstract problems that uses computational principles. CT focuses on solving problems through systematic steps rather than simply generating solutions (Alfaro-Ponce et al., 2023). Wing (2006) states that computational thinking is a combination of problem-solving and cognitive strategies applicable across a variety of situations. Furthermore, according to Gadnadis (2016), CT and mathematics are closely related because both involve logical structures and creative problem-solving abilities. Consequently, CT can help students think creatively, critically, and analytically when facing complex problems.

Consequently, Yeni et al. (2024) found a gap between teachers' knowledge of CT and its use in schools. Teachers were aware of CT, but they still struggled to create learning activities, formulate CT questions, and incorporate it into the classroom. This situation suggests that prospective teachers must be equipped with computational thinking skills from an early age so they can design relevant learning and encourage students to develop CT.

Recent findings indicate a difference between "das sein," meaning students lack strong CT skills for living and teaching in the technological era, and "das sollen," meaning students still have low skills, especially in generalization, algorithms, and

abstraction (Shuxia & Xinhong, 2024; Wei et al., 2023). Furthermore, students often rush when reading problems, causing them to overlook important information (Avila & Caballes, 2024). This situation highlights the importance of improving students' CT skills.

Problems requiring pattern identification, algorithmic step development, and generalization processes cannot be solved by students with low CT skills. They often fail to draw accurate conclusions, understand solution patterns, and comprehend the problem (Lisa et al., 2023). These results indicate that students' CT competencies still need to be strengthened through more effective pedagogical approaches.

To meet this need, this study aims to improve and measure students' computational thinking skills through the Integral Calculus course. This course is very complex, both in understanding the basic concepts (integrals and antiderivatives) and in terms of applying formulas, theorems, graphs, and integral applications to measure area and volume. A comparable problem was found by Ferrer (2016). This includes determining the limits of integration, choosing the appropriate integration strategy, and applying integral concepts in real-world situations. Therefore, integral mathematics is an interesting field for improving computational thinking skills comprehensively.

In addition to these empirical findings, the literature review indicates that research on developing computational thinking skills in higher education is very limited. Rich et al. (2019) found that while numerous studies have been conducted at the elementary level on the relationship between computational thinking and mathematics-science learning, there is little research in higher education. Gasaymeh and AlMohtadi (2024) indicated that CT research is scarce in higher education, and Liu (2023) noted a gap between theory and practice, particularly regarding how educators use computational thinking. This condition is also emphasized. Furthermore, several obstacles exist. The variety of CT measurement instruments is very limited (Pelánek & Effenberger, 2023), and there is no empirical evidence that CT improves problem-solving skills (Irawan et al., 2024).

This research focuses on the Gayo tradition of cooperation, known as Alang Tulung. Alang Tulung means that people who are sick, experiencing work difficulties, or need assistance must be helped collectively (Lestari, 2002). A strong foundation for building a project-based learning model stems from a combination of cultural and historical values. This model will enhance students' social skills and collaboration skills, in addition to improving their academic abilities. However, the Gayo culture of cooperation has been eroded by modernization, individualistic lifestyles, and technological advancements (Putri et al., 2023). Education and social campaigns continue to strive to keep this tradition relevant for future generations.

In this study, technology integration is demonstrated through the use of Blended Project-Based Learning (Blended PjBL). However, the Alang Tulung Gayo (ATG) concept emphasizes discipline, cooperation, mutual assistance, and collective

responsibility, although the model development does not solely focus on digital aspects (Rosdaniah & Hilliyani, 2024). PjBL values can be applied in the planning, implementation, and reporting of projects in a disciplined and collaborative manner. This cultural integration teaches students social responsibility, communication, cooperation, leadership, and improves learning outcomes (Antonyuk et al., 2026).

By leveraging the flexibility of offline and online learning, the Alang Tulung Gayo-based Blended PjBL model aims to address some of these challenges. The Sevima EdLink platform allows students to continue project work outside the classroom, participate in discussions via Zoom or Google Meet, and receive online guidance from their teachers. This approach expands the scope for collaboration without being constrained by time or location. Furthermore, the integration of ATG values into the learning process helps students recognise and practise the Gayo culture of cooperation, which supports the development of computational thinking skills.

Based on a literature review and analysis of various previous studies, no research has been found that specifically develops a Blended PjBL model based on Alang Tulung Gayo to enhance the computational thinking skills of mathematics education students. Given this urgency, this study aims to describe an operational framework that synergises local wisdom with modern learning technologies to enhance students' CT skills. Furthermore, this study aims to examine the improvement in the computational thinking skills of mathematics education students through the Alang Tulung Gayo-based Blended PjBL model, as well as to evaluate whether the Alang Tulung Gayo culture can act as a catalyst in supporting the success of digital transformation in higher education.

Literature Review

Computational Thinking and Mathematical Cognition

Computational thinking emphasizes how computing and its concepts aid the learning process. According to Palop et al. (2025), computational thinking is defined as the ability to abstraction, algorithmic thinking, automation, decomposition, and generalization, all of which are considered essential for problem-solving and mathematical reasoning. In 2006, Jeannette Wing revived the term "computational thinking" in an article titled "Computational Thinking." Wing (2006) argued that computational thinking is not specific to computer science but is a style of thinking that everyone should learn in the computing era and should therefore be incorporated into every child's analytical skills. Computational thinking has the potential to provide strategies for solving problems in various fields in the future. This is in line with Denning's (2019) opinion that computational thinking is a way of thinking that provides understanding of various aspects of today's highly sophisticated world, where the tools, methods, and epistemology of science have been transformed by computational thinking. Therefore, learning computational thinking has many benefits, namely helping someone manage data effectively and efficiently. There

are five indicators of computational thinking that will be used in this study using the opinions of Lee et al. (2014) and Harmini et al. (2020), namely: (1) decomposition: the ability to use problem-solving techniques that have been learned to sort information and break down complex problems into smaller, more manageable subsections, (2) pattern recognition: the ability to detect and distinguish patterns or characteristics that are the same or different between subsections of a problem, (3) abstraction: the ability to sort important information from irrelevant details to create a general model or solution structure that represents the problem, (3) Algorithm: the ability to design logistical steps used to compile a solution to a given problem, and (4) Generalization: the ability to assess how correct and appropriate the general rules (principles) made from the patterns found are, and to test the limits of these rules on various types of similar problems.

The Evaluation of Blended Project-Based Learning (Blended PjBL)

The Blended Project-Based Learning (Blended PjBL) model was developed to maximize the benefits of integrating offline and online learning within the context of project completion. This model provides a balance between collaborative activities and the development of 21st-century skills. Simultaneously, Blended PjBL also contributes to improving computational thinking skills through the stages of decomposition, algorithm design, and project planning, as well as strengthening students' digital skills (Cole et al., 2020; Lam & Dongola, 2020). The implementation of Blended Learning in this study was supported by the Sevima EdLink e-learning platform. The platform's effectiveness has been proven strong, as demonstrated by data from the 2019–2020 Academic Year Even Semester Midterm Exam, which achieved an average score of 90.83 (Marlina, 2020). These findings indicate that Blended Learning-based mathematics learning with the help of Sevima EdLink is relevant to support the Independent Learning–Independent Campus (MBKM) policy. The suitability of using this platform is also reinforced by students' positive perceptions of its effectiveness and ease of use (Nurasiza et al., 2022).

Synergy of Culturally Responsive Pedagogy (CRP) and Technology

Culturally Responsive Pedagogy (CRP) states that learning is most effective when it leverages students' cultural strengths. In education, indigenous knowledge systems, such as the Alang Tulung Gayo tradition, provide existing social activities that students can use to collaboratively complete projects using blended learning. The integration of Alang Tulung Gayo values in Blended PjBL is systematically applied at each stage of the project. In the Start with the Essential Question stage, the Mango Lo value is applied as students collaborate to identify essential questions and determine the project theme. This process supports the development of early computational thinking skills and fosters prosocial attitudes. In the Design a Plan for the Project stage, the Berlat/Berhelat and

Mango Lo values are reflected through the lecturer's guidance activities in developing the project plan. The Mah Atur value is evident when students work collaboratively to determine tools, strategies, and completion stages in a structured manner.

The Create a Schedule stage showcases the *Berumpah-umpah* value through deliberation activities to develop a group work schedule. In this phase, the Berlat/Berhelat value is again evident as students independently seek references and alternative solutions. Next, the "Monitor the Students and the Progress of the Project" stage implements the values of Bejamu, Berlat/Berhelat, and Mango Lo, which are reflected in discussions, collaboration, and mutual assistance among students under the supervision of lecturers.

In the "Assess the Outcome" stage, the "Berumpah-umpah" value is realized through presentations of project results and feedback through deliberation within the group to reach consensus. The final stage, "Evaluate the Experience," integrates the values of Berumpah-umpah, Mah Atur, and Tung Upah. Students reflect collectively on their learning experiences, collaborate on conclusions, and receive appreciation from their lecturers as a token of appreciation for the process and achievements.

Methodology

This study is empirical in nature, conducted within a Research and Development (R&D) framework using the Plomp development model. As emphasized by Sugiyono (2019) research and development is a scientific method used to design, manufacture, and validate educational products. This process ensures that the resulting model is not only theoretically sound but also tested in practice. To achieve this, a trial and improvement process was applied to create a learning model (Joyce & Weil, 2003).

The Plomp model used in this study consisted of three stages: (1) preliminary research, (2) prototyping, and (3) assessment. The subjects of this study were 52 students of the Mathematics Education Study Program at IAIN Lhokseumawe in the 2024–2025 academic year, enrolled in the Integral Calculus course. The research procedure was designed in an integrative manner to achieve the main objective, namely synergizing the Alang Tulung Gayo culture with the Blended Project-Based Learning framework to develop computational thinking indicators.

The research instruments included pre-test and post-test assessments of computational thinking skills (decomposition, pattern recognition, abstraction, algorithms, and generalization), complemented by observation sheets documenting the implementation of the Alang Tulung Gayo-based Blended PjBL model. Instrument validity was confirmed through expert review, and reliability was tested using Cronbach's Alpha (Creswell, 2018):

$$\alpha = \left(\frac{k}{k-1} \right) \left(1 - \frac{\sum \sigma_b^2}{\sigma_t^2} \right) \quad (1)$$

Where k is the number of test items, $\sum \sigma_b^2$ is the variance of the test item scores, and σ_b^2 is the variance of the total score. In addition to the test instrument, there is also an observation sheet for the implementation of the blended project-based learning model based on Alang Tulung Gayo.

The learning procedure followed a cycle of the blended PjBL model integrated with Alang Tulung Gayo values (*Mango Lo, Mah Atur, Bejamu, Berumpah-umpah, and Tung Upah*). Students first conducted problem analysis independently on the Sevima EdLink platform, then engaged in collaborative discussions to solve problems systematically through deliberation and consensus.

The effectiveness of the model was measured using a pre-experimental design with pre-test and post-test. The improvement in students' computational thinking abilities was analyzed using the Normalized Gain (N-Gain) formula (Wahab et al., 2021):

$$g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \quad (2)$$

Where S_{post} is the final test score, S_{pre} is the initial test score, and S_{max} is the maximum possible score. Statistical significance was tested using the Wilcoxon Signed-Rank Test. This empirical procedure demonstrates that the proposed framework is not only theoretically grounded but also validated through quantitative evidence, linking Gayo cultural values with measurable improvements in 21st-century skills.

Results

The presentation of this study's results is organized based on the three main phases in Plomp's development model: the preliminary research phase, the prototyping phase, and the assessment phase. This structure is designed to address the research objectives hierarchically and systematically.

Preliminary Research Phase

This stage aims to identify the fundamental needs in Integral Calculus learning at IAIN Lhokseumawe. Context analysis results indicate that students' low CT capabilities stem from a disconnect between abstract material and their social reality. Initial data suggest that without cultural integration, the use of the Sevima EdLink digital platform tends to be primarily administrative. These findings validate the urgency of formulating a framework that integrates the local wisdom of Alang Tulung Gayo as the foundation for developing a modern learning model.

Prototyping Phase

The first objective of this study, formulating an operational framework, was realized in this phase. Based on academic validation by subject matter experts and instructional designers, the prototype model was deemed highly valid for enhancing the pillars of CT. The primary output of this phase is the Operational Framework, visualized in Figure 1.



Figure 1. Operational Framework of Alang Tulung Gayo-Based Blended Project-Based Learning for Enhancing Computational Thinking

This framework operates as a closed-loop cycle where the digital ecosystem (Sevima EdLink) serves as the central hub, and the local wisdom values of Alang Tulung Gayo act as catalysts at each stage. Each cultural value is systematically linked to a specific Computational Thinking (CT) pillar, ensuring that sociocultural practices reinforce cognitive development.

Phase 1: Initiation – *Mango Lo* Students collaborate to identify essential questions and form teams. → CT Connection: Stimulates **Decomposition** (breaking down problems into manageable parts).

Phase 2: Management – *Mah Atur* Leadership and organization guide project planning. → CT Connection: Strengthens Algorithm Design (structuring systematic steps).

Phase 3: Support – *Bejamu* Peer support and mutual assistance during project monitoring. → CT Connection: Enhances Pattern Recognition (identifying similarities across solutions).

Phase 4: Consensus – *Berumpah-umpah* Group deliberation and validation of outcomes. → CT Connection: Fosters Abstraction (distinguishing essential from non-essential information).

Phase 5: Accountability – *Tung Upah* Reflection and evaluation of project results. → CT Connection: Promotes Generalization (applying solutions to broader contexts).

Overall, this framework analysis demonstrates that digital transformation in higher education will achieve maximum effectiveness when technology is not merely viewed as a technical tool but is integrated with students' sociocultural value systems. This model explicitly addresses the research objective of fostering the development of Computational Thinking capabilities through a culturally responsive pedagogy.

Assessment Phase

This phase addresses the second and third research objectives, namely conducting an empirical analysis of improvements in CT capabilities (specifically decomposition and algorithms) and evaluating the role of local traditions as catalysts.

Empirical Analysis of CT Capabilities

The results of the implementation among 52 students showed a significant escalation in cognitive capabilities, as summarized in Table 1.

Table 1. Empirical Analysis of CT Ability Improvement (N=52)

CT Components	Pre-test (Mean)	Post-test (Mean)	N-Gain Score	Effectiveness Category
Decomposition	45.20	82.40	0.68	Moderate
Pattern Recognition	48.50	85.10	0.71	High
Abstraction	42.10	78.50	0.63	Medium
Algorithm Design	38.40	80.20	0.68	Moderate
Generalization	35.60	77.30	0.65	Moderate
Total Average	41.96	80.70	0.67	Moderate

The data in Table 1 shows that the Decomposition ability increased from 45.20 to 82.40. This proves that students are able to break down complex integral problems into simpler sub-problems. Meanwhile, in the Algorithm Design component, there

was an increase of 0.68, indicating students' ability to formulate systematic solution steps.

Evaluation of Local Traditions as Catalysts for Digital Transformation

An evaluation of the role of local traditions shows that the values of Alang Tulung act as a catalyst that transforms digital interactions into more meaningful ones.

Table 2. Relationship Between Alang Tulung Indicators and CT Pillars

Local Tradition Activities (Catalyst)	Digital Manifestations (EdLink)	Stimulated CT Pillars	Evaluation Results
<i>Mango Lo & Mah Atur</i>	Group Formation & Task Division	Decomposition	Accelerating the decomposition of the problem structure
<i>Bejamu</i>	Online Forum Discussion	Pattern Recognition	Facilitates the identification of similar solutions
<i>Berumpah-umpah</i>	Virtual Meeting/Chat Consensus	Abstraction	Filtering core mathematical models
<i>Tung Upah</i>	Project Submission & Peer Review	Algorithm & Generalization	Ensuring the validity of solution steps

Evaluation results indicate that the *Berumpah-umpah* tradition serves as the strongest catalyst in supporting digital transformation. This digital deliberation transforms a platform that was initially purely technical into a meaningful space for dialectic discourse. Without this local tradition as a catalyst, the use of digital platforms tends to be individualistic; however, with the values of "Alang Tulung," digital transformation in higher education (specifically at IAIN Lhokseumawe) becomes more inclusive and effective in improving students' academic performance.

Discussion

The implementation of the Blended PjBL-based Alang Tulung model, developed through Plomp's design cycle, demonstrates that the success in scaling up students' Computational Thinking (CT) capabilities is rooted in the strong sociocultural synergy within the model's design. Findings from the preliminary research and prototyping phases (Figure 1) demonstrate that the local wisdom of Alang Tulung Gayo is not merely a social supplement but a cognitive framework that mitigates students' barriers to the abstract material of Integral Calculus. The Mango Lo and Mah Atur phases, which operationally guided the formation of team commitment and digital project management, were found to systematically

trigger the pillars of Decomposition and Algorithm Design. This aligns with the theory of digital social constructivism proposed by Liu et al. (2022), in which a collaborative structure based on social norms familiar to students is able to minimize cognitive load in solving complex mathematical problems.

The observed escalation of CT capabilities during the assessment phase (Table 1) provides empirical evidence of this model's effectiveness, with an average increase in N-Gain scores of 0.67. Interestingly, the Pattern Recognition pillar achieved the highest effectiveness, indicating that the Bejamu phase or peer support via Sevima EdLink facilitates students in collectively identifying similarities in solution structures. Improvements in the decomposition and algorithm components the primary focus of this research confirm the argument by Zhang et al. (2024) that project-based learning integrated with communal accountability yields deeper and "portable" understanding. This process enables students not only to solve a specific problem but also to transfer knowledge to broader problem contexts through generalization skills.

Furthermore, the role of local wisdom as a catalyst for digital transformation is most prominent during the deliberative consultation phase, or "Berumpah-umpah." As shown in the evaluation of the catalyst's role (Table 2), this digital consultation serves as a cognitive turning point for students' to perform precise abstraction. This local tradition transforms the digital platform from a mere administrative tool into a meaningful space for dialectic discourse. This finding supports the idea proposed by Nazyrova et al. (2025) that successful digital transformation in higher education does not occur through the replacement of local values by technology, but rather through the strengthening of human interaction within it. The integration of Gayo values ensures that information technology does not become something foreign to students, but rather a tool that reinforces their academic identity.

Overall, the integration of Plomp's phases in developing this model provides a theoretical generalization that future mathematics learning models must adopt a culturally responsive pedagogy. The results of this study demonstrate that the development of 21st-century digital competencies, such as Computational Thinking, will achieve maximum effectiveness when built upon a foundation of sociocultural values deeply rooted in the learning community. In line with Tang et al. (2025) perspective, inclusive digital transformation in higher education requires a balance between technological sophistication and local wisdom to ensure the sustainability of learning outcomes and students' emotional and cognitive engagement.

Although this framework is rooted in the Gayo culture through the concept of *Alang Tulung*, the underlying principles are universal. Values such as mutual cooperation, collective responsibility, and collaborative problem-solving are not unique to Indonesia but resonate across cultures worldwide. For instance, the African

philosophy of *Ubuntu* emphasizes solidarity and shared humanity (Gumede, 2026; Olawumi & Mavuso, 2026), while the Javanese tradition of *Gotong Royong* highlights collective work and mutual aid (Bowen, 1986). By reframing the framework as a method for integrating local cultural values into Project-Based Learning and Computational Thinking, educators in different regions can adapt it to their own cultural contexts. This demonstrates that culturally responsive pedagogy is not limited to one tradition but can serve as a global model for enhancing student engagement and 21st-century skills (Anofuechi & Klaasen, 2013).

Practical Example To illustrate the framework in practice, consider a project in the Integral Calculus course where students are tasked with calculating the area under a curve using digital tools. In the *Mango Lo* phase, students collaborate to formulate the essential question: "How can we calculate the area bounded by a function using digital technology?" During the *Berumpah-umpah* phase, they engage in online discussions via the Sevima EdLink platform to filter relevant information and reach consensus on the appropriate mathematical model. This process not only strengthens abstraction and algorithmic skills but also fosters collaborative attitudes that can be applied in diverse cultural settings. By presenting such concrete examples, the framework becomes more accessible to practitioners and demonstrates its adaptability beyond the Indonesian context (Makamure, n.d.; Zhang et al., 2024).

Conclusion

This study concludes that the formulation of the Alang Tulung-Based Blended PjBL operational framework through Plomp's development cycle successfully created a valid, practical, and effective learning ecosystem. The synergy between Gayo local wisdom and the Sevima EdLink platform has proven capable of significantly enhancing students' Computational Thinking (CT) capabilities, achieving moderate to high effectiveness across all CT pillars. These findings affirm that local traditions, particularly the *Berumpah-umpah* deliberation phase, act as an essential cognitive catalyst in supporting the success of digital transformation in higher education through the strengthening of culturally responsive mathematical abstraction and algorithm design processes.

The primary strength of this research lies in the originality of the framework, which integrates specific sociocultural values into the syntax of digital learning an approach that introduces novelty into the modern mathematics education literature. The methodological balance between R&D development models and quantitative analysis provides a strong foundation for the validity of the product while demonstrating that technology can be implemented in a humanistic manner without erasing students' local identities. This demonstrates that inclusive digital transformation can be achieved when technological platforms are infused with social values deeply rooted in the learning community.

However, this study has several limitations, including its specific geographical and cultural scope within the Gayo community; therefore, generalizing this model

to other cultural contexts requires adaptation to relevant local values. Furthermore, the implementation being limited to a single semester in the Integral Calculus course highlights the need for future longitudinal studies to test the sustainability of students' CT skill retention in other science courses. The success of this model also remains highly dependent on the stability of digital infrastructure and internet accessibility, which continue to pose challenges in the equitable distribution of educational transformation across various regions. Ultimately, this framework contributes to the broader discourse on culturally responsive pedagogy by demonstrating how local traditions can be systematically integrated into digital learning models to strengthen 21st-century skills worldwide.

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