



IMPASSES IN MATHEMATICAL PROBLEM SOLVING: TYPOLOGIES AND RESOLUTION MECHANISMS IN PRODUCTIVE STRUGGLE

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ABSTRACT

Productive struggle is a cognitive process in which students engage with challenging mathematical tasks, experience a temporary cognitive impasse (the stuck phase), and eventually find a way forward without immediate direct teacher assistance. This study presents a systematic literature review of primary studies on productive struggle published between 2019 and 2026, with particular attention to impasse phases and their resolution mechanisms. Following the PRISMA 2020 protocol, literature was searched across Google Scholar, ERIC, DOAJ, and official journal repositories. Of 76 initially identified articles, 39 studies met the inclusion criteria. Narrative thematic synthesis focused on three areas: 1) the methodological landscape and contextual distribution of research, 2) the typology of impasses and related mathematical task-design features, and 3) teacher facilitation dynamics in impasse resolution. The findings show a dominance of qualitative methods (61.5%), middle school student participants (35.9%), and limited research in culturally contextualized educational settings. The study highlights implications for designing contextualized geometry tasks under Indonesia's Kurikulum Merdeka, particularly through the integration of ethnomathematics.

Keywords: Productive Struggle, Cognitive Impasse, Mathematical Problem Solving, Teacher Facilitation

ABSTRAK

Productive struggle merupakan proses kognitif ketika siswa terlibat dalam tugas matematika yang menantang, mengalami kebuntuan kognitif, dan berupaya menemukan jalan keluar tanpa bantuan langsung dari guru. Penelitian ini menyajikan systematic literature review terhadap studi primer mengenai productive struggle yang diterbitkan pada periode 2019–2026, dengan perhatian khusus pada kebuntuan yang dialami siswa dan mekanisme penyelesaiannya. Mengikuti protokol PRISMA 2020, penelusuran literatur dilakukan melalui Google Scholar, ERIC, DOAJ, dan repositori jurnal resmi. Dari 76 artikel yang teridentifikasi pada tahap awal, sebanyak 39 studi memenuhi kriteria inklusi. Sintesis tematik naratif difokuskan pada tiga aspek, yaitu: 1) lanskap metodologis dan distribusi kontekstual penelitian, 2) tipologi kebuntuan dan karakteristik desain tugas matematika yang berkaitan, dan 3) dinamika fasilitasi guru dalam penyelesaian kebuntuan. Hasil menunjukkan dominasi metode kualitatif (61,5%), partisipan siswa sekolah menengah pertama (35,9%), serta masih terbatasnya penelitian dalam konteks pendidikan berbasis budaya. Penelitian ini menyoroti implikasi bagi perancangan tugas geometri kontekstual dalam Kurikulum Merdeka, khususnya melalui integrasi etnomatematika.

Kata Kunci: Upaya Kognitif Produktif, Kebuntuan Kognitif, Pemecahan Masalah Matematis, Fasilitasi Guru

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I. INTRODUCTION

Over the last thirty years, there has been a clear shift in mathematics education from a focus on mastering procedures to an emphasis on developing conceptual understanding through experience with genuinely challenging tasks. The NCTM states that effective mathematics teaching uses the difficulties students experience as valuable opportunities to deepen their understanding rather than viewing them as obstacles that should be eliminated immediately (Pasquale, 2016). The TIMSS 2019 framework also regards persistence in problem solving as a key skill developed through engagement with mathematical tasks (Khotimah, 2021), while Polya (2014) stated that every discovery, no matter how small, brings intellectual satisfaction to those who make it through their own efforts.

Productive struggle is consistently described as a process involving active engagement with tasks that require effort, critical thinking, and persistence; it is characterized by obstacles, errors, and a sense of cognitive discomfort as students continue searching for solutions. In his study of 186 struggle episodes in middle school mathematics classrooms, Warshauer (2015) identified four types of struggle: procedural, conceptual, expressive, and motivational. He also showed that teacher responses involving questioning as a form of scaffolding are more effective in leading students toward deeper understanding than simply providing answers (Young et al., 2024).

A critical stage in this process occurs when students reach a point at which they cannot determine the next useful step in solving a mathematical problem. In this article, an impasse is distinguished from productive struggle because productive struggle refers to the broader process of continuously engaging with a difficult task, whereas an impasse refers specifically to the point at which the learner's current strategies or understanding are insufficient to allow further progress. The term stuck phase describes the period during which students are unable to make progress after reaching such an impasse. Therefore, productive struggle, impasse, and stuck phase are related but distinct concepts: productive struggle refers to the entire process, an impasse denotes the moment when progress is disrupted, and the stuck phase describes the period during which the learner is unable to move forward. Whether this phase is handled successfully-through well-designed tasks or appropriate teacher support-will determine whether the struggle becomes productive or develops into frustration that negatively affects learning motivation (Hakim et al., 2025).

Since 2011, research on productive struggle has continued to increase, but systematic syntheses of this research remain limited. The scoping review conducted by Young et al. (2024), which examined 45 documents published between 2011 and 2020, found that most studies were qualitative, involved teachers as participants, and rarely specified the mathematical content or grade level. In contrast, the bibliometric analysis by Mufliva et al. (2025) mapped global research trends but remained descriptive and did not examine the mechanisms underlying productive struggle itself.

This gap provides the basis for the present article. Although existing syntheses, such as the scoping review by Young et al. (2024) and the bibliometric analysis by Mufliva et al. (2025), examine productive struggle from a broad perspective, they do not specifically organize classroom-based primary studies according to the typologies of impasses, the characteristics of stuck phases, and the mechanisms through which such episodes are resolved. To our knowledge, none of the systematic literature reviews examined in this study has specifically addressed these two aspects together—that is, the different forms of impasse experienced during mathematical problem solving and the mechanisms used to resolve them. The novelty of the current review therefore lies not simply in extending the publication period, but in treating impasses and stuck phases as specific areas of analysis within productive struggle and systematically synthesizing their typologies and resolution mechanisms. This need is increasingly important in the context of Indonesia's Kurikulum Merdeka, which promotes differentiated learning and critical reasoning as part of the *Profil Pelajar Pancasila* (Pancasila Student Profile). On this basis, this article aims to synthesize 39 primary studies on productive struggle published between 2019 and 2026, focusing on three main areas of discussion. First, it examines the methodological landscape and contextual distribution of productive struggle research within this period. Second, it analyzes how the typology of identified impasses relates to the characteristics of the mathematical task designs that trigger them. Third, it examines how teacher facilitation patterns influence the direction of impasse resolution, whether toward meaningful understanding or unproductive frustration.

II. RESEARCH METHOD

This article employs a systematic literature review (SLR) method following the PRISMA 2020 protocol (Page et al., 2021). The selection of this method is based on three considerations. First, no systematic review has specifically examined productive struggle mechanisms at the classroom level for the 2019–2026 period. Second, the SLR enables structured mapping of methodological variation, contexts, and educational levels across primary studies while also filtering out secondary studies to avoid double counting. Third, unlike a scoping review that emphasizes mapping the breadth of the literature, the SLR in this article is directed toward substantive synthesis to identify consistent patterns and themes.

The literature search was conducted in 2026 across four sources: Google Scholar, ERIC (Education Resources Information Center), DOAJ (Directory of Open Access Journals), and ResearchGate/official journal repositories accessed via DOI links. The search was restricted to publications from 2019 to 2026. No language restriction was applied at the search stage; however, only articles available in full text in English or Indonesian were retained at the eligibility stage. The same four Boolean search strings were applied to each source: 1) "productive struggle" AND

"mathematics", 2) "productive struggle" AND "problem-solving", 3) "daya juang produktif" AND "matematika", and 4) "cognitive demand" AND "productive struggle" AND "classroom". The number of records retrieved from each source is presented in table 1.

Table 1. Search Strings, Period, and Records Retrieved per Source

Source	Period	Records retrieved
Google Scholar	2019–2026	41
ERIC	2019–2026	15
DOAJ	2019–2026	12
ResearchGate/Official Journal Repositories	2019–2026	8
Total		76

Source: Authors' Literature Search, **Year:** 2026

The 76 records from all sources were combined into a single list, and duplicates were identified by comparing titles, authors, publication years, and DOIs. Seven duplicate records were removed, leaving 69 unique records for screening. Screening followed the PRISMA 2020 stages shown in Figure 1 and proceeded in two steps. First, the full texts of all 69 unique records were assessed for eligibility based on the inclusion and exclusion criteria. Twenty-four records were excluded: eight lacked a clear mathematics context, nine did not adequately operationalize productive struggle, and seven had full texts that could not be verified. This left 45 records. Second, the study types of the remaining records were verified, and six secondary studies were excluded: two scoping reviews, two bibliometric analyses, and two meta-analyses/narrative reviews. This resulted in 39 eligible reports for further assessment.

The inclusion criteria were as follows: 1) articles published between 2019 and 2026, 2) primary empirical studies that collected or analyzed original data using quantitative, qualitative, or mixed methods, with each independent study counted once, 3) a clear mathematics learning context, 4) productive struggle was addressed as a directly analyzed variable or phenomenon, and 5) full-text accessibility and verifiability in English or Indonesian. The exclusion criteria included articles without a clear mathematics context; conceptual, theoretical, practitioner, and opinion papers without an empirical basis; all secondary studies, including scoping reviews, bibliometric analyses, meta-analyses, content analyses of the literature, and narrative reviews; articles published before 2019, which were used only as theoretical background; and additional reports of a study, dataset, or program already included, which were merged with the primary report to avoid double counting.

Further assessment of the 39 eligible reports resulted in the removal or merging of 13 entries (figure 1). One entry was published before 2019 (Warshauer, 2015). Five entries were non-empirical: four conceptual or practitioner papers (Baker et al., 2020; Dinapoli, 2021; Dixon & Mahoney, 2024; Townsend et al., 2018) and one content analysis of the literature (Young et al., 2025). Seven entries

were extended subsamples, subcases, or continuations of other entries and were therefore merged with their primary reports: Russo et al. (2021), Trinter & Hughes (2021), Vazquez et al. (2020), Biccard (2024), Salazar (2022), Sayster & Mhakure (2020a), and Bolyard et al. (2024). Russo et al. (2020) addressed different research questions using different instruments and were therefore retained as two studies. The final corpus comprised 26 independent studies.

Data from each selected study were extracted using a synthesis matrix adapted from the framework of Young et al. (2024), covering six dimensions: author and year, research objective, methodology, sample, educational level, and key findings. The synthesis was conducted through narrative thematic analysis following the guidance of Popay et al. (2006). The themes were developed through a systematic comparison of the extracted findings across studies. First, relevant findings related to the review objectives were identified and coded. Similar findings were then grouped into categories based on recurring concepts, patterns, and characteristics reported across the studies. These categories were subsequently compared and refined to form broader themes corresponding to the three domains of the review. The themes were reviewed against the findings of the included studies to ensure that they accurately represented the evidence reported in the primary research rather than relying on individual study findings. Quality assessment was used to evaluate the methodological rigor of the included studies and to inform the interpretation of the synthesized findings. Studies were not excluded solely on the basis of quality unless this was specified in the eligibility criteria. The identification, screening, eligibility assessment, and inclusion process followed the PRISMA 2020 protocol (Page et al., 2021), as illustrated in figure 1.

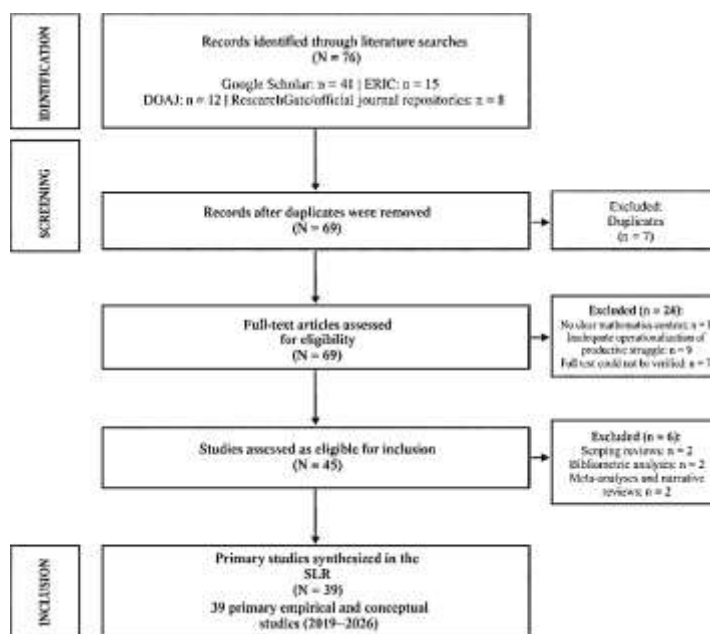


Figure 1. PRISMA 2020 Flow Diagram

III. RESULTS AND DISCUSSION

Among the 39 primary studies synthesized, publication years were concentrated in the 2020–2024 period, with the highest peaks in 2023 and 2024, each contributing more than one-quarter of all included studies. The complete characteristics of the 39 studies are presented in table 2.

Table 2. Characteristics Matrix of 39 Primary Studies on Productive Struggle in Mathematics Learning (2019-2026)

Author & Year	Research Objective	Method and Participants	Key Findings
Khalil et al. (2025)	To evaluate students' perceptions of teacher support before, during, and after productive struggle-based learning	The study used a mixed-methods design and involved high school students.	Students with appropriate teacher support show higher engagement; affective and cognitive scaffolding influence the quality of struggle.
Russo et al. (2021)	To compare elementary school teachers' attitudes toward productive struggle in remote and face-to-face settings	The study used a mixed-methods design and involved in-service elementary school teachers.	Struggle facilitation is more difficult online; positive teacher attitudes remain a key factor in the quality of struggle.
Vazquez et al. (2020)	To examine the relationship between parental beliefs about productive struggle and homework assistance behavior	The study used a quantitative design and involved parents of K–6 students at the elementary school level.	Positive parental beliefs are associated with a guiding rather than answer-giving approach to assistance; a mediation effect was found.
Salazar (2022)	To examine the effect of productive struggle on the mathematical skills of Grade 8 students	The study used a quantitative quasi-experimental design and involved Grade 8 middle school students.	The experimental group showed significant improvements in reasoning and problem solving.
Bolyard et al. (2024)	To support middle school teachers' understanding of productive struggle through a three-year STEM professional development program	The study used a qualitative design and involved in-service middle school STEM teachers.	Teachers develop their understanding gradually; a major barrier is the tendency to provide scaffolding too early.
Trinter & Hughes (2021)	To explore teachers' experiences as interdisciplinary curriculum designers in the context of productive struggle	The study used a qualitative narrative design and involved in-service middle school teachers.	Teachers who experience struggle during curriculum design are better able to design high-cognitive-demand tasks.
Baker et al. (2024)	To examine the productive struggle of Grade 5 students and teachers in exploring area and perimeter	The study used a qualitative case study design and involved Grade 5 students and teachers at the	Teacher and student struggle mutually influence each other; teachers who openly engage in struggle encourage students to take greater cognitive risks.

Author & Year	Research Objective	Method and Participants	Key Findings
		elementary school level.	
Biccard (2024)	To examine the role of productive struggle in contextual mathematical modeling	The study used a qualitative task-analysis design and involved university students.	Struggle emerges during problem interpretation and model validation; diverse task entry points produce different struggle patterns.
Russo et al. (2020)	To describe elementary school teachers' beliefs about the role of struggle in mathematics learning	The study used a qualitative open-ended survey and involved in-service elementary school teachers.	Most teachers believe struggle is important but are concerned about its negative emotional impact.
Dixon & Mahoney (2024)	To identify how challenging tasks facilitate productive struggle and richer mathematical understanding	This was a non-empirical task-design study with a conceptual focus on elementary school students.	Tasks with multiple entry points and a low-floor, high-ceiling structure elicit productive struggle without triggering frustration.
Mufliva et al. (2024)	To analyze the relationship between problem-solving ability and productive struggle among elementary school students	The study used a qualitative descriptive design and involved elementary school students.	Higher problem-solving ability is associated with more focused struggle.
Oktavia et al. (2026)	To explore students' argumentation skills based on their level of productive struggle	The study used a qualitative phenomenological design and involved middle school students.	Students with high levels of struggle produce more elaborated arguments and deeper justifications.
Baker et al. (2020)	To describe the characteristics of productive struggle in actual mathematics learning practice	This was a non-empirical video-scenario study focusing on in-service teachers in professional development across educational levels.	Productive struggle is evident when students ask "why" rather than merely "how"; withholding direct assistance produces more meaningful struggle.
Weingard en (2025)	To explore preservice mathematics teachers' experiences with productive struggle	The study used a qualitative reflective design and involved preservice mathematics teachers in higher education.	Participants experience cognitive and emotional struggle; personal experience with struggle enhances pedagogical empathy.
Casler-Failing (2024)	To examine the facilitation of productive struggle in an online mathematics methods course	The study used a qualitative narrative-reflection design and involved preservice high school teachers in higher education.	Online learning narrows the facilitation space; anonymity reduces anxiety but also reduces the depth of discussion.

Author & Year	Research Objective	Method and Participants	Key Findings
Safak et al. (2021)	To analyze preservice teachers' lesson plans regarding strategies for supporting productive struggle	The study used qualitative document analysis and examined lesson plans developed by preservice elementary and middle school teachers.	Preservice teachers' lesson plans tend to include overly detailed scaffolding, potentially reducing the space for struggle.
Young et al. (2025)	To redefine the productive struggle construct through content analysis of mathematics education literature	This was a non-empirical content analysis of academic literature and did not involve research participants.	The productive struggle construct does not yet have a consistent operational definition; core components include cognitive discomfort, active persistence, and meaningful resolution.
Sayed (2022)	To use GeoGebra to develop productive struggle and deep understanding in geometry and measurement	The study used a quantitative experimental design and involved middle and high school students.	GeoGebra-based exploration enhances productive struggle; students using the software demonstrate deeper conceptual understanding.
Sayster & Mhakure (2020b)	To explore high school students' productive struggle in simplifying rational algebraic expressions	The study used a qualitative case study design and involved high school students.	Struggle is classified as procedural, conceptual, and expressive; procedural struggle is the most dominant but also the most easily facilitated.
Sayster (2023)	To analyze high school students' productive struggle in trigonometry, particularly their responses to trigonometric identity proofs	The study used a qualitative task-analysis design based on the ATD framework and involved high school students.	Identity proofs elicit distinctive epistemic struggle; students are often caught between analytic and synthetic strategies, and scaffolding proves most effective.
DiNapoli (2023)	To distinguish the concepts of grit, persistence, and perseverance in mathematics learning	This was a non-empirical conceptual study and did not involve research participants.	Perseverance differs from grit because it encompasses a dimension of understanding; productive struggle requires perseverance rather than mere endurance.
DiNapoli & Miller (2022)	To examine the role of conceptual-thinking scaffolding in supporting student perseverance during problem solving	The study used a qualitative case study design and involved middle school students.	Conceptual question-based scaffolding is more effective in fostering perseverance and producing more focused struggle.
Lambert & Tan (2020)	To examine the challenges of supporting productive struggle among students with disabilities in pandemic-era online learning	The study used a qualitative narrative design and involved teachers of students with disabilities across	Students with disabilities require highly personalized scaffolding; the pandemic exacerbated access barriers and cognitive isolation.

Author & Year	Research Objective	Method and Participants	Key Findings
		elementary, middle, and high school levels.	
Russo et al. (2020)	To explore the relationship among teachers' enjoyment of mathematics, attitudes toward struggle, and instructional time allocation	The study used a quantitative survey design and involved early-career in-service elementary school teachers.	Teachers who enjoy mathematics are more tolerant of student struggle; curriculum pressure acts as a barrier to allocating time for struggle.
Khalil (2024)	To examine the effectiveness of an educational program in improving middle school students' achievement and productive struggle	The study used a quantitative quasi-experimental design and involved middle school students.	The exploratory learning-based program measurably increased productive struggle scores.
Murdoch et al. (2020)	To examine the relationship among feeling heard, inclusive education, and productive struggle	The study used a qualitative phenomenological design and involved students from diverse backgrounds across elementary through high school levels.	Students who feel heard by their teachers engage in struggle more confidently; psychological safety is a prerequisite for productive struggle.
Townsend et al. (2018)	To present strategies for supporting all types of learners in productive struggle	This was a non-empirical practitioner-oriented study focusing on middle school teachers and students.	Differentiation should not eliminate the space for struggle; low-floor, high-ceiling and think-aloud strategies broaden access to struggle.
Melani et al. (2023)	To analyze the mathematical modeling ability and productive struggle of middle school students in problem-solving tasks	The study used a qualitative descriptive design and involved middle school students.	Mathematical modeling ability is positively associated with productive struggle; students with low levels of struggle fail to move beyond the problem-translation stage.
Mefiana et al. (2023)	To examine students' mathematical understanding based on their level of productive struggle	The study used a qualitative descriptive-comparative design and involved middle school students.	Students with high productive struggle demonstrate substantially deeper relational understanding than instrumental understanding.
Samosir et al. (2023)	To analyze Grade 7 students' solutions to contextual problems based on sentence structure and productive struggle	The study used a qualitative descriptive design and involved Grade 7 middle school students.	Task sentence structure influences the type of struggle; complex-sentence tasks elicit linguistic struggle before mathematical struggle.
Russo et al. (2021)	To compare elementary school teachers' attitudes toward	The study used a quantitative comparative survey	The learning context moderates the relationship between

Author & Year	Research Objective	Method and Participants	Key Findings
	productive struggle in online and face-to-face contexts using an extended subsample	and involved in-service elementary school teachers.	teacher attitudes and the quality of struggle facilitation.
Trinter & Hughes (2021)	To describe teachers' involvement in productive struggle as curriculum designers across different subcases	The study used a qualitative comparative narrative design and involved in-service middle school teachers.	Teachers who engage in struggle during curriculum design develop more positive dispositions; a transfer effect to actual classrooms was identified.
Vazquez et al. (2020)	To analyze parental beliefs about productive struggle and their relationship with homework assistance using an extended subsample	The study used a quantitative correlational design and involved parents of elementary school students.	The effect of parental beliefs is stronger among the more highly educated group; school-based parent education proved effective.
Estrella et al. (2020)	To examine how teachers learn to maintain the cognitive demand of tasks through lesson study	The study used a qualitative action-research and lesson-study design and involved in-service teachers at the elementary and middle school levels.	Lesson study helps teachers refrain from simplifying tasks; cognitive demand is maintained through collaborative question planning.
Bolyard et al. (2024)	To support middle school teachers' understanding of productive struggle in a STEM professional development program as a continuation of Curtis et al. (2023)	The study used a qualitative case study design and involved in-service middle school STEM teachers.	Teachers' understanding develops gradually over three years; collaborative reflection proves to be the most effective mechanism for change.
Sayster & Mhakure (2020b)	To classify types of productive struggle among high school students simplifying algebraic expressions using the ATD framework	The study used a qualitative task-analysis design based on the ATD framework and involved high school students.	The ATD framework helps distinguish technical and theoretical struggle; teachers need to respond to each type using different strategies.
Biccard (2024)	To examine productive struggle in mathematical modeling from the perspective of diverse task entry points in an extended case	The study used a qualitative task-analysis design and involved university students.	Modeling tasks with different entry points produce nonlinear struggle patterns; the most productive struggle occurs when students compare multiple models.
Salazar (2022)	To examine the effect of productive struggle on Grade 8 students'	The study used a quantitative quasi-experimental design	ANCOVA confirms a significant effect of productive struggle after controlling for

Author & Year	Research Objective	Method and Participants	Key Findings
	mathematical skills with ANCOVA and prior ability; the largest effect is using additional analysis involved Grade 8 found in proportional of covariance middle school students. reasoning.		

Source: Authors' Synthesis, **Year:** 2026

Thirty-nine records were initially identified. Seven records were determined to be extended reports, subsamples, or continuations of studies already included (Biccard, 2024; Bolyard et al., 2024; Russo et al., 2021; Salazar, 2022; Sayster & Mhakure, 2020; Trinter & Hughes, 2021; Vazquez et al., 2020). These records were merged with their primary studies to avoid double counting, resulting in 32 independent studies. The methodological characteristics of the 39 primary studies indicate a distinct pattern of research approaches. To provide a comprehensive overview of the proportional distribution of research designs used during the 2019–2026 period, the distribution of methodological approaches is presented in figure 2.

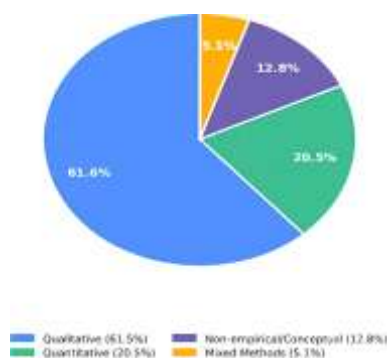


Figure 2. Distribution of Methodological Approaches

Beyond methodological characteristics, mapping the educational levels at which the studies were conducted is also important for understanding research trends. The distribution of educational levels across the included studies is presented in figure 3.

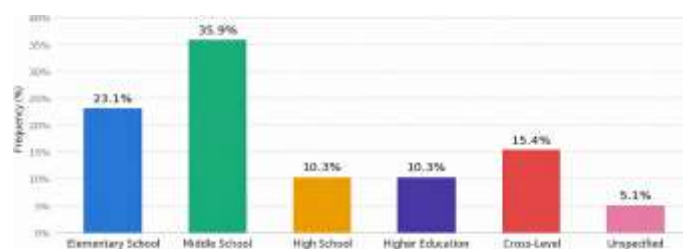


Figure 3. Bar Chart of Educational Level Distribution of Research Participants

Equally important, identifying the types of participants involved in the studies provides insight into shifts in research perspectives. The distribution of participant types across the 2019–2026 literature corpus is presented in figure 4.

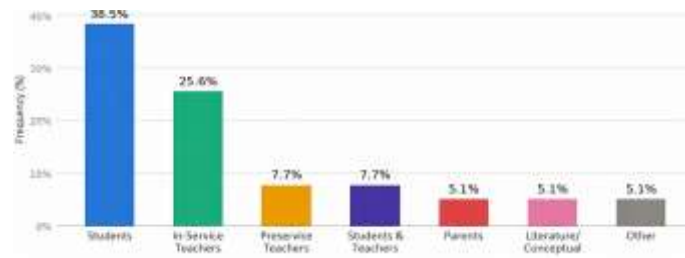


Figure 4. Bar Chart of Participant Type Distribution

A. Methodological Landscape and Contextual Distribution of Productive Struggle Research

Productive struggle is a highly situational phenomenon because it depends on the specific interaction among the task, the student, and the teacher's response at a given moment. Qualitative approaches, particularly case studies and episode analyses, allow researchers to capture these nuances in detail, which is difficult to achieve using deductive quantitative instruments. This methodological preference also reflects the dominant epistemological view in the field: an impasse cannot be adequately measured through scores alone but needs to be understood through observations of students' thinking processes.

However, the dominance of qualitative methods also reveals cumulative limitations that warrant attention. Of the 39 studies synthesized, only eight used quantitative methods, and most measured productive struggle indirectly, for example, through problem-solving scores or gain scores on achievement tests. Instruments specifically designed to measure productive struggle as a standalone construct remain rare. Khalil (2024) is one of the few studies that employed a specific productive struggle scale to measure students' productive struggle in mathematics, although its application remained limited to a specific educational context. Young et al. (2024) further affirmed that the absence of a consistent operational definition is a major obstacle to developing valid measurement instruments that are replicable across contexts. This condition hinders the systematic accumulation of comparable evidence.

Furthermore, research on mathematical problem solving indicates that internal student factors, such as beliefs about their own capabilities (self-efficacy), play an important role in determining how students confront difficulties when solving problems. Yastuti et al. (2025) found that students' problem-solving profiles differ according to their level of self-efficacy; students with high self-efficacy tend to be more persistent, more willing to try various strategies, and better able to manage impasses productively than students with low self-efficacy. This finding reinforces the argument that productive struggle is determined not only by task characteristics but also by students' affective dispositions when facing mathematical challenges.

In addition to internal student factors, instructional design can create structured opportunities for students to experience productive struggle. Abida et al. (2023) showed that implementing a

Creative Problem Solving (CPS) model supported by learning modules can improve students' problem-solving abilities because the model encourages students to identify problems, formulate strategies, and evaluate solutions independently before receiving direct assistance from the teacher. In the context of productive struggle, the CPS steps provide an intentionally designed “space for being stuck,” in which students have the opportunity to experience an impasse, try various approaches, and eventually find a way forward through reflection and discussion.

A notable shift is also observed in participant composition. Whereas the majority of participants in the 2011–2020 period were teachers, both in-service and preservice, the data for the current period show that students have become the largest group (38.5%), surpassing in-service teachers (25.6%). This shift reflects a meaningful development in the field: researchers are moving from mapping teacher beliefs and readiness toward directly observing how students experience and navigate the stuck phase in real classrooms. Consequently, the findings generated during this period more closely reflect students' actual learning experiences rather than merely teachers' perceptions of those experiences.

The middle school level dominates the studies (35.9%), which is understandable given that the middle school mathematics curriculum involves a substantial conceptual transition, particularly from arithmetic to algebra and from descriptive to analytical geometry, making productive struggle relatively likely to occur. Meanwhile, studies at the high school level (10.3%) and in higher education (10.3%) remain limited, even though topics such as calculus, trigonometry, and formal proofs have considerable potential to generate meaningful struggle. This imbalance in educational-level distribution suggests that the available findings on productive struggle are not yet fully representative of the broader spectrum of mathematics learning.

B. Mapping the Typologies of Impasses and Mathematical Task Design Characteristics

The four-part typology-namely, procedural, conceptual, expressive, and motivational struggle-continues to serve as the classification framework in nearly all synthesized studies. This indicates that the framework is broadly applicable across contexts and educational levels. Masitoh et al. (2024) applied a similar typology in a study of high school students simplifying rational algebraic expressions and found that procedural struggle was the dominant type and the most easily facilitated by teachers. Conversely, conceptual struggle was less frequent but more difficult to overcome.

These findings affirm that not all types of impasses respond in the same way to the same interventions, giving typological classification practical value for classroom teachers. More recent studies have also begun to uncover nuances not fully captured by Warshauer's four types. VanLehn et al. (2021) found a distinctive form of struggle, namely epistemic struggle, in trigonometric identity proofs: high school students are often caught between analytic and synthetic strategies. This impasse is not a matter of not knowing the procedure or not understanding the concept, but rather of

uncertainty about the direction of proof to pursue. This type of struggle has not yet been explicitly accommodated in Warshauer's typology, and its existence indicates that the framework may need to be expanded to capture the epistemological dimension of higher-order mathematical thinking.

Melani et al. (2023) reported another important finding for the Indonesian context: in Grade VII contextual tasks, linguistic struggle can precede and trigger mathematical struggle. When the task narrative uses long sentences or a culturally unfamiliar context, students encounter their first impasse not at the mathematical stage but at the stage of understanding what the task is asking. This means that mathematics tasks designed within ethnomathematical contexts may produce two layers of impasse: the first is interpretive-cultural in nature, and the second is mathematical. Teachers who are unaware of this first layer risk providing scaffolding at the wrong level, thereby missing a critical facilitation moment.

Regarding task design, there is fairly strong consensus among the synthesized studies. Dixon & Mahoney (2024) and Townsend et al. (2018) concluded that tasks with multiple entry points and a low-floor, high-ceiling structure create opportunities for more students to engage with the problem in their own way. As a result, the impasses experienced tend to be more varied and cognitively rich, reflecting the depth of each student's thinking rather than merely an inability to follow a single procedure. Kartal et al. (2017) highlighted that mathematical modeling tasks can create opportunities for students to engage in productive struggle as they develop, evaluate, and refine their mathematical models. The tension between these models compels students to think more deeply about the assumptions underlying each approach.

Technology can also trigger impasses within productive struggle. Sayed (2022) found that GeoGebra-based exploration in the geometry unit prompted students to engage in more meaningful struggle than those in the conventional group. This is likely because the software allows students to see the direct consequences of each decision, making errors in thinking visually apparent and sparking curiosity to correct them. In other words, the appropriate use of technology does not eliminate impasses but makes them more visible and easier to detect. However, tasks that are excessively challenging without adequate initial scaffolding may result in unproductive cognitive processes, particularly when students reach an impasse (Sayster & Mhakure, 2020). The boundary between productive struggle and unproductive frustration is determined by the extent to which students still have sufficient cognitive resources to continue their efforts.

C. Dynamics of Teacher Facilitation Patterns in Impasse Resolution

Across all findings, the teacher facilitation domain shows the most consistent and convergent patterns. Nearly all studies that examine the role of teachers arrive at the same conclusion: question-based scaffolding is more effective than providing direct procedural assistance (Baker et al., 2024). What distinguishes more recent studies from earlier ones is the depth of analysis into why this is the

case and what makes this approach difficult for teachers to implement. The consistency of this finding across contexts, educational levels, and methodologies provides fairly strong evidence that this pattern is not a methodological artifact but rather reflects genuine learning dynamics.

Putro (2021) observed that struggle becomes productive when students begin asking “why” rather than merely “how.” This shift in the type of questions students ask signals that they are no longer merely searching for a procedure but are beginning to build understanding. Teachers who can recognize this signal and refrain from immediately providing an answer give students space to reach that point. Melani et al. (2023) showed in greater detail that effective scaffolding does not involve completely withholding assistance, but rather providing assistance at the conceptual level—through questions that help students clarify their own thinking—rather than at the procedural level, which may take over the student's thinking process.

Notably, several studies show that this capacity does not develop automatically, even when teachers already understand the concept of productive struggle theoretically. Kyriakides et al. (2017) found that a three-year professional development program involving systematic and guided critical reflection had a greater impact on teachers’ teaching skills. This suggests that brief training on productive struggle, as is commonly provided in one- or two-day workshops, is likely insufficient to change teaching behaviors that have been established over many years. Meaningful change requires time, community, and sustained reflection.

Melani et al. (2023) offered a mechanism that appears more promising: lesson study. When teachers design, observe, and reflect on learning together, they naturally learn to distinguish the type of assistance that enriches struggle from the type that actually ends it. Lesson study creates space to discuss specific classroom moments that are difficult to replicate through lecture-based training. Trinter & Hughes (2021) added an interesting dimension: teachers who have personally experienced productive struggle during curriculum design were shown to be better able to design high-cognitive-demand tasks and more tolerant of student impasses. Personal experience with the stuck phase may build pedagogical empathy that cannot be achieved through conceptual understanding alone.

The affective and relational dimensions also receive considerable attention in the synthesized studies. Dixon & Mahoney (2024) found that feeling heard by the teacher is a prerequisite for students to engage in struggle. Without the assurance that mistakes will not be ridiculed, students tend to choose the safer path: remaining silent, copying, or pretending to understand. This affirms that facilitating productive struggle is not merely a matter of questioning techniques but also of building a classroom climate in which cognitive vulnerability is accepted as a natural part of the learning process. Baker et al. (2024) reinforce this finding by showing that teachers who openly display their own struggle when confronting tasks can create a psychological climate that encourages students to take greater cognitive risks.

The online learning context adds another layer of challenge. Russo et al. (2021) and Casler-Failing (2024) found that limitations in real-time feedback in online environments significantly narrow the space for facilitating productive struggle. Teachers lose access to the nonverbal cues that typically help them determine when a student is genuinely struggling and when the student has already given up. Lambert & Schuck (2021) found that students with disabilities experience this impact more acutely: they require more personalized and responsive scaffolding, which is difficult to deliver effectively through a screen. This situation highlights the fact that productive struggle is not a context-free phenomenon but is deeply dependent on the quality of interaction between teachers and students.

D. Implications for the Indonesian Educational Context

These findings have direct relevance to the implementation of Indonesia's Kurikulum Merdeka. This curriculum explicitly promotes differentiated learning, critical reasoning, and the values embodied in the *Profil Pelajar Pancasila*, which closely align with the principles of productive struggle. The principles of multiple entry points and low-floor, high-ceiling task design that consistently emerge in the studies can be operationalized in project-based teaching modules (*Modul Ajar*) or contextual mathematics tasks. For mathematics teachers developing ethnomathematics-based geometry tasks—for instance, using the architectural context of the Menara Kudus tower or geometric patterns found in coastal batik—these principles involve designing tasks with varied entry points so that students with different ability levels can begin engaging with the problem from their own perspectives.

Regarding teacher professional development, the finding that the capacity to withhold scaffolding requires years to develop provides a strong argument for a professional development model based on learning communities (*Komunitas Belajar/KomBel*), which is currently promoted by the Indonesian Ministry of Education (Kemendikbudristek). *KomBel* meetings that discuss actual classroom episodes—similar to the lesson study mechanism shown to be effective by Melani et al. (2023) have the potential to become spaces in which teachers gradually develop effective facilitation skills for productive struggle. This model is far more promising than one- or two-day training sessions that are primarily informative but do not significantly change teaching behavior.

Of the 39 synthesized studies, none were conducted in Islamic educational institutions or madrasahs. Yet millions of Indonesian students learn mathematics in madrasah environments, where classroom dynamics, pedagogical values, and teacher-student relationships may differ from those in public schools. The Indonesian studies included in this synthesis, such as Mefiana et al. (2023), and Melani et al. (2023), were conducted in public secondary schools. The question of whether effective struggle facilitation patterns identified in public schools in Australia or the United States apply in the same way to madrasah classrooms in Central Java or South Kalimantan remains unanswered. This

gap opens a broad and highly relevant research opportunity for the development of mathematics education in Indonesia.

E. Research Limitations

Several limitations should be considered when interpreting the findings of this synthesis. First, the literature search was conducted using only four major sources: Google Scholar, ERIC, DOAJ, and journal repositories accessed via DOI links. Highly reputable subscription databases such as Scopus and Web of Science were not included because of access limitations, leaving open the possibility that some relevant and high-quality primary studies were missed.

Second, this article included only studies published in English and Indonesian; therefore, research on productive struggle published in other languages-such as Arabic, Mandarin, or Turkish-was not included in the synthesis. Third, publication bias cannot be ruled out. Studies with positive findings tend to be more likely to be published and retrieved, potentially making the overall picture of the effectiveness of productive struggle in this synthesis slightly more optimistic than it actually is. Fourth, the majority of the primary studies originated from the United States, Australia, and parts of the Middle East, while studies from Southeast Asia particularly those conducted in religious educational contexts such as Indonesian madrasahs, remain very limited and are not yet represented in this corpus.

IV. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The systematic synthesis of these 39 primary studies indicates that impasses in mathematical problem solving are not simply random occurrences but critical junctures that can be described through identifiable types and addressed through different forms of task design and teacher facilitation. The four types of struggle-procedural, conceptual, expressive, and motivational-provide a foundational framework for understanding mathematical struggle, while more recent studies have expanded this discussion to include epistemic and linguistic forms of struggle. Across the reviewed studies, task designs featuring multiple entry points and low-floor, high-ceiling characteristics, together with question-based scaffolding and the deliberate withholding of immediate assistance, emerged as recurring approaches for supporting students in working through cognitive impasses and developing mathematical understanding. However, given the methodological diversity of the reviewed studies, these patterns should be interpreted as recurring tendencies rather than evidence of a universally effective instructional combination.

B. Recommendations

Future research should examine productive struggle and impasse resolution across broader geographic and institutional contexts, including Islamic educational settings and local

ethnomathematical contexts. Further studies are also needed to develop more standardized instruments for identifying and examining impasses in mathematical problem solving. In addition, future research should investigate how different task designs and teacher facilitation strategies contribute to the productive resolution of cognitive impasses across different educational levels and learning contexts.

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