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SYNTHESIS OF A "FISIKA CAMPURSARI" CONCEPTUAL FRAMEWORK BASED ON THE CLASSIFICATION, FORMULATION, AND VALIDATION OF MATHEMATICAL MODELS OF EVERYDAY PHYSICAL PHENOMENA: SYSTEMATIC LITERATURE REVIEW (SLR)

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ABSTRACT

This study aims to synthesize a conceptual framework for Fisika Campursari by identifying the characteristics and classifications of mathematical models of everyday physical phenomena and examining their formulation approaches, solution methods, validation strategies, and limitations. A systematic literature review (SLR) was conducted using a descriptive qualitative approach to examine 18 scientific articles published between 2017 and 2026. The data were analyzed through multidimensional classification, comparative analysis, and thematic synthesis guided by three research questions. The findings indicate that mathematical models of everyday physical phenomena exhibit multidimensional characteristics, encompassing mechanistic, phenomenological, statistical, and data-driven approaches. Mathematical representations include algebraic equations, differential equations, equilibrium models, probability distributions, and scaling relationships. Solution methods comprise analytical, numerical, and data-based estimation approaches, whereas evaluation strategies include theoretical consistency, numerical accuracy, empirical validation, and the suitability of instructional tools. The synthesis yielded a Fisika Campursari conceptual framework integrating phenomenon identification, physical principles, abstraction, mathematical formulation, solution, model testing, and interpretation. This study concludes that integrating model characteristics and their evaluation strategies makes a conceptual contribution to contextual physics modeling by establishing a cross-phenomenon analytical

framework. Nevertheless, empirical validation is still required to assess the framework's applicability to diverse physical phenomena.

KEYWORDS: Fisika Campursari; Mathematical Modeling; Everyday Physical Phenomena; Conceptual Framework; Systematic Literature Review.

INTRODUCTION

Mathematical modeling transforms observable physical phenomena into quantitative representations through variables, parameters, assumptions, and relationships among physical quantities. This process is important because everyday events often involve complex physical mechanisms. Akbar et al. (2021) demonstrated that rope skipping can be formulated using nonlinear differential equations to explain changes in rope shape. Margaretta et al. (2019) showed that the bending of an elastic column under its own weight is associated with mechanical stability and scaling relationships near a critical condition. Tsai et al. (2022) modeled stones skipping across water by analyzing hydrodynamic forces and successive stages of motion. These three studies illustrate the mathematical problems that can arise from everyday activities. However, different phenomena do not necessarily require the same model structure. Differences in dominant mechanisms and analytical objectives determine the formulations and outputs obtained. Therefore, the simplification of phenomena and the limits of their physical assumptions need to be examined comparatively.

Model diversity is also evident in transportation and fluid systems. Millah (2023) employed the Lighthill–Whitham–Richards model to represent the effects of vehicle density and road conditions on traffic flow. Putra and Gunawan (2018) applied the finite volume method to describe queue formation and dissipation using conservation equations. In contrast, Saberi et al. (2020) used an analogy with disease transmission to explain the propagation of congestion in urban networks. In coffee brewing, Liang et al. (2021) developed a desorption equilibrium model to predict solute concentrations and extraction yield. Mo et al. (2023) linked the microstructure of the coffee matrix to flow properties using X-ray microtomography and particle-based hydrodynamic simulations. Yun (2017) investigated liquid-droplet rebound in terms of geometry, inertia, and surface tension. Observation scale, simplification, and predictive objectives yield different models even for related phenomena. Cross-phenomenon comparison is therefore necessary to identify their conceptual regularities.

Mathematical modeling also extends to human movement, sports, manufactured objects, and environmental phenomena. Mao et al. (2021) employed an inverted pendulum model to

estimate human gait parameters from inertial sensor measurements. Brink et al. (2023) formulated the dynamics of football players during dribbling using differential equations and movement- and behavior-related parameters. Obayashi et al. (2023) used robotic testing and probabilistic modeling to relate paper-airplane geometry to flight characteristics. Razzak et al. (2025) represented wind-speed variability using a Weibull distribution through spreadsheet-based simulation. These four studies demonstrate that models are not always derived directly from laws of motion. Some are mechanistic, whereas others prioritize empirical patterns, statistical estimation, or data-driven relationships. Consequently, predictive accuracy is not synonymous with the completeness of a physical explanation. Classification is needed according to the phenomenon, formulation, mathematical structure, complexity, and model function.

Model quality is also determined by the suitability of its formulation and solution. Akbar et al. (2021) employed an analytical approach for small rope deflections and numerical solutions when nonlinear effects became more pronounced. Ramadhan and Novitrian (2026) demonstrated that the choice of integrator for a double pendulum affects energy stability and the consistency of long-term simulations. Tsai et al. (2022) combined force analysis, simplification based on successive stages of motion, and numerical solutions to generate predictions. By contrast, the equilibrium model of Liang et al. (2021) illustrates the value of simplification when relationships among components can still be adequately explained. Mathematical complexity is therefore not the sole indicator of model quality. More complex models require additional data and computational resources but do not necessarily improve interpretability. Accordingly, analytical, numerical, and data-driven methods, together with their limitations, need to be compared.

The meaning of validation also varies across studies. Pacala and Mendaño (2025) compared estimates of gravitational acceleration obtained from a simple pendulum using manual measurements and Tracker video analysis. Habib and Pramudya (2021) compared coupled-pendulum oscillation frequencies derived from theory, ultrasonic sensors, and video analysis, while also reporting measurement errors. Mao et al. (2021) used a motion measurement system as a reference for evaluating gait-parameter estimates, whereas Liang et al. (2021) tested model outputs against experimental data. In contrast, Millah (2023) and Putra and Gunawan (2018) primarily demonstrated system behavior under simulation scenarios. Muharam et al. (2024) used a rubber-powered car and Tracker to design instructional experiments, whereas Sumardi et al. (2022) evaluated an oscillation simulation tool for physics education. Educational suitability, numerical consistency, and empirical agreement

are distinct indicators. Treating them as equivalent risks overstating the strength of the evidence. A synthesis must distinguish theoretical consistency, numerical evaluation, empirical validation, and educational utility.

Within the corpus of 18 articles, the principal gap is the fragmentation of discussions across groups of phenomena and stages of modeling. Studies of mechanics and games, transportation, fluids, biomechanics, and statistical modeling generally emphasize the specific problems addressed by each investigation. Classification, abstraction, solution, and validation have not been integrated into a comparative framework within this corpus. Furthermore, the depth of evidence is uneven because the studies employ experimental, simulation-based, probabilistic modeling, and instructional-development designs. This gap is conceptual and does not negate the contributions of earlier research. A mapping framework that explicitly distinguishes model objectives, assumptions, outputs, testing strategies, and domains of validity is needed. Such mapping enables comparisons across contexts without obscuring their physical mechanisms. A systematic review is therefore required to integrate the available evidence.

Fisika Campursari is positioned as an integrative perspective on everyday phenomena rather than a universal mathematical theory. Games, human activities, household practices, transportation, and the environment provide sources of physics problems. The synthesis of Akbar et al. (2021), Margaretta et al. (2019), Liang et al. (2021), and Saberi et al. (2020) demonstrates opportunities to connect mechanisms and mathematical representations across different contexts. The framework links phenomena, physical principles, assumptions, formulation, solution, testing, and domains of validity. This sequence allows assumptions to be revised following testing. The distinctive contribution of the present study lies in combining multidimensional classification with the evaluation of modeling quality from the Fisika Campursari perspective. Its contribution is a framework for comparing and developing contextual modeling approaches. The claim of novelty is restricted to the reviewed corpus rather than the entire global literature.

This study aims to synthesize the characteristics, methods, and conceptual patterns of modeling everyday physics through a systematic literature review. The first objective is to map model classifications according to phenomena, formulations, equations, and functions. The second is to compare model formulation, solution, validation, and limitations. The third is to establish the foundational principles of a Fisika Campursari conceptual framework. The first research question is: What are the characteristics and classifications of mathematical models used to represent various everyday physical phenomena, as reported in previous

studies? The second asks: How have formulation approaches, solution methods, and validation strategies for mathematical models been applied in previous studies, and what limitations have been reported? The third asks: What conceptual patterns, research gaps, and mathematical modeling principles can be synthesized from the literature to formulate a Fisika Campursari conceptual framework? The answers are intended to distinguish evidence-based findings from conceptual proposals that require further examination.

METHODS

This study employed a systematic literature review (SLR) design with a descriptive qualitative approach involving comparative analysis and thematic synthesis. The units of analysis were scientific articles addressing mathematical models of everyday physical phenomena. The initial research corpus consisted of 18 articles published between 2017 and 2026, as listed in the matrix of previous studies. Inclusion criteria encompassed articles investigating contextual physical phenomena, employing mathematical representations, and describing their modeling approaches and findings. Articles that were irrelevant, duplicated, or insufficiently informative for data extraction were excluded. The research instrument was a data extraction matrix containing article identification, phenomenon characteristics, theories, variables, assumptions, equation formulations, solution methods, validation strategies, findings, and research limitations. Data were collected through comprehensive reading of the articles, identification of relevant information, coding of study characteristics, and recording of findings according to the three research questions. To ensure reproducibility, the search process should explicitly document databases, keyword combinations, search dates, numbers of identified articles, and reasons for exclusion. This search-history information was not available in the supplied document and must therefore be supplemented based on the search process actually undertaken.

Data analysis was designed to employ qualitative content analysis, comparative analysis, and thematic synthesis to identify conceptual regularities across the literature. The first stage classified models according to phenomenon categories, mechanistic or empirical approaches, mathematical structures, complexity, and scientific functions. The second compared mathematical formulations, analytical methods, numerical solutions, data-driven approaches, and simplifying assumptions. The third evaluated validation strategies in terms of theoretical consistency, numerical accuracy, empirical agreement, and limitations of testing. This distinction considers the characteristics of the studies by Liang et al. (2021), Ramadhan and Novitrian (2026), and Sumardi et al. (2022), which applied different forms of evaluation. The

fourth stage grouped findings according to similarities, differences, gaps, and conceptual relationships among models. The classification results addressed RQ1, the analysis of formulation and validation addressed RQ2, and the synthesis of patterns and gaps addressed RQ3. The synthesis was then used to formulate a Fisika Campursari conceptual framework by linking phenomenon identification, physical principles, abstraction, formulation, solution, validation, and model interpretation. Analytical consistency was checked by tracing each category and conclusion back to its source article and documenting coding decisions to ensure a transparent and auditable research process.

RESULTS

1. General Characteristics of the Reviewed Studies

The review covered 18 scientific articles published between 2017 and 2026. These articles examined mathematical modeling across various physical phenomena associated with everyday activities and environments. Based on their objects of investigation, the studies were divided into six principal categories: mechanics and games; oscillations and dynamical systems; transportation; fluids and mass transfer; human activities and manufactured objects; and statistical modeling and education. Each category contained three articles in the principal classification used for synthesis. The mathematical representations identified included algebraic equations, ordinary differential equations, partial differential equations, equilibrium relationships, probability functions, and scaling relationships. Modeling approaches encompassed mechanistic, phenomenological, statistical, and data-driven models. The research methods reported in the articles included experiments, numerical simulation, theoretical analysis, sensor-based measurements, and the development of simulation tools. A summary of the study classification is presented in Table 1.

Table 1. Classification of articles according to the physical phenomena investigated.

Phenomenon category	Authors and year	Articles	Principal representation
Mechanics and games	Akbar et al. (2021); Margaretta et al. (2019); Tsai et al. (2022)	3	Differential equations, elasticity, force analysis
Oscillations and dynamical systems	Pacala & Mendaño (2025); Habib & Pramudya (2021); Ramadhan & Novitrian (2026)	3	Pendulum models, normal modes, Hamiltonian mechanics
Transportation	Millah (2023); Putra & Gunawan (2018); Saberi et al. (2020)	3	Conservation models, PDEs, network ODEs

Phenomenon category	Authors and year	Articles	Principal representation
Fluids and mass transfer	Liang et al. (2021); Mo et al. (2023); Yun (2017)	3	Equilibrium models, hydrodynamics, dimensionless parameters
Human activities and manufactured objects	Mao et al. (2021); Brink et al. (2023); Obayashi et al. (2023)	3	Mechanistic models, ODEs, probabilistic approaches
Statistics and education	Razzak et al. (2025); Muharam et al. (2024); Sumardi et al. (2022)	3	Weibull distribution, kinematics, oscillation simulations
Total		18	

2. Classification Results for Mechanical and Oscillatory Modeling

Within the mechanics and games category, Akbar et al. (2021) developed a second-order nonlinear differential equation model to explain the profile of a rotating rope during rope skipping. That study reported a scaling relationship with an exponent of approximately −0.31. Margaretta et al. (2019) employed a slender elastic-column model and reported a scaling exponent of approximately 0.485 for changes in column configuration under self-weight. Tsai et al. (2022) formulated the motion of a nonspinning stone skipping across the water surface through hydrodynamic force analysis and numerical solutions. Within the oscillations category, Pacala and Mendaño (2025) estimated gravitational acceleration at 9.9 ± 1.8 m/s² using traditional measurement and 10.0 ± 0.9 m/s² using Tracker. Habib and Pramudya (2021) reported measurement errors of 18.4% using Tracker and 12.55% using an ultrasonic sensor for a coupled-pendulum system. Ramadhan and Novitrian (2026) compared several numerical integration algorithms for a double-pendulum system. Their comparison found that the Gauss–Legendre method provided better long-term energy stability under the reported test configuration.

3. Results of Transportation and Fluid Dynamics Modeling

The transportation category comprised three studies employing different mathematical approaches. Millah (2023) used the Lighthill–Whitham–Richards equation and the Greenshields relationship to simulate changes in vehicle density and speed. Putra and Gunawan (2018) applied the finite volume method to simulate shock waves, queue growth, and the dissipation of vehicle density. Saberi et al. (2020) applied an epidemic-analogy model based on ordinary differential equations to describe the propagation and reduction of traffic congestion using transportation-network data from six cities. In the fluids category, Liang et al. (2021) used a desorption equilibrium model for coffee brewing and reported a relatively

constant extraction yield of approximately 21% under the tested conditions. Mo et al. (2023) combined X-ray microtomography and smoothed particle hydrodynamics simulation to describe flow through the porous structure of a coffee matrix. Their study reported variations in permeability, tortuosity, and porosity distribution in the examined samples. Yun (2017) employed geometric parameters and the Weber number to investigate the rebound of ellipsoidal droplets on superhydrophobic surfaces. That study reported a contact-time reduction of at least 30% for the tested aspect ratios compared with spherical droplets.

4. Results of Modeling Human Activities, Manufactured Objects, and Environmental Phenomena

Mao et al. (2021) applied an inverted pendulum model to estimate human walking parameters from inertial sensor measurements. Their study reported correlations above 0.9 for several motion parameters and a mean step-length bias of approximately 0.006 m. Brink et al. (2023) used two ordinary differential equations to represent the interaction between an attacker and a defender in a one-on-one dribbling situation. Model parameters were determined by fitting the equations to football match-tracking data. Obayashi et al. (2023) employed Gaussian mixture models and Bayesian optimization to classify paper-airplane flight characteristics. Their study identified trajectory categories including nose dive, glide, and recovery glide. For environmental phenomena, Razzak et al. (2025) developed a spreadsheet-based simulator to generate wind-speed distributions using the shape and scale parameters of the Weibull distribution. Muharam et al. (2024) used a rubber-powered car and the Tracker application to observe kinematic characteristics in an instructional experimental design. Sumardi et al. (2022) developed an oscillation simulation using MATLAB and reported suitability evaluations of the tool by lecturers and students.

5. Identification of Mathematical Formulation Approaches

Analysis of the research documents identified several mathematical formulation approaches employed in previous studies. A mechanistic approach was found in Akbar et al. (2021), Margaretta et al. (2019), and Tsai et al. (2022), who used principles of mechanics as the basis for constructing equations. Conservation-law approaches were applied by Millah (2023) and Putra and Gunawan (2018) in traffic-flow models. Liang et al. (2021) employed an equilibrium approach to explain the characteristics of coffee extraction. The adaptation of established theoretical models was demonstrated by Pacala and Mendaño (2025) through pendulum period relationships and by Mao et al. (2021) through inverted pendulum

representations. Data-driven approaches were observed in Brink et al. (2023) through player-motion parameter estimation and in Obayashi et al. (2023) through probabilistic clustering. Razzak et al. (2025) employed a probability distribution function as a mathematical representation of wind-speed phenomena. These approaches differed in the foundations of equation construction, types of parameters, mathematical structures, and reported model outputs.

6. Identification of Model Solution Methods

The identified solution methods included analytical, numerical, and computational approaches, as well as data-driven estimation. Akbar et al. (2021) used analytical solutions under small rope-deflection conditions and numerical solutions for larger deflections. Tsai et al. (2022) applied numerical algorithms to calculate stone trajectories and the number of skips. Millah (2023) employed an upwind scheme, whereas Putra and Gunawan (2018) used the finite volume method to solve transportation models. Ramadhan and Novitrian (2026) compared Runge–Kutta, Störmer–Verlet, implicit midpoint, and Gauss–Legendre methods in double-pendulum simulations. Mo et al. (2023) used particle-based simulations to describe fluid dynamics within the coffee matrix. Obayashi et al. (2023) applied probabilistic clustering and data-driven optimization to paper-airplane design characteristics. Sumardi et al. (2022) used a MATLAB interface to visualize oscillatory motion. These solution methods generated outputs such as motion profiles, variable distributions, trajectories, estimated parameters, and simulation visualizations.

7. Identification of Model Validation Strategies and Limitations

Data extraction revealed several strategies for assessing models: theoretical comparison, numerical evaluation, empirical validation, and instructional-tool evaluation. Pacala and Mendaño (2025), Habib and Pramudya (2021), and Mao et al. (2021) used measurement data to compare model outputs with reference values or systems. Tsai et al. (2022) and Liang et al. (2021) reported comparisons between mathematical predictions and experimental results. Ramadhan and Novitrian (2026) evaluated energy stability, integration error, and convergence characteristics of numerical methods. Millah (2023) and Putra and Gunawan (2018) primarily presented simulation results based on traffic scenarios. Akbar et al. (2021) reported visual or qualitative comparisons of rope profiles. Muharam et al. (2024) reported a mean student response of 71.63%, whereas Sumardi et al. (2022) presented percentage-based suitability ratings for a simulation tool. The recorded limitations included restricted

experimental conditions, simplifying model assumptions, measurement uncertainty, parameter dependence, and the availability of comparative data. In some articles, tests of the models under conditions different from those investigated were not reported.

8. Synthesis of Conceptual Patterns in Fisika Campursari Modeling

The synthesis of the research corpus identified several modeling components used to investigate everyday physical phenomena. These components include identifying phenomena, determining physical principles, selecting variables and parameters, and establishing model assumptions. A subsequent component involves mathematical formulation using equations suited to the characteristics of the system. Models are then solved using analytical, numerical, or data-driven methods, as appropriate to the reviewed studies. Testing procedures within the corpus included comparisons with theory, experimental findings, observational data, and numerical evaluations. The studies also included interpretations of physical quantities and limitations arising from the conditions and assumptions employed. In the synthesis document, these components were organized into conceptual relationships linking contextual phenomena, abstraction, formulation, solution, testing, and interpretation. The result is presented as a Fisika Campursari conceptual framework derived from organizing the modeling characteristics identified in the reviewed articles.

DISCUSSION

This study synthesized the characteristics, formulations, solution methods, and validation strategies of mathematical models of everyday physical phenomena based on 18 scientific articles published between 2017 and 2026. The synthesis indicates that everyday phenomena can be represented by mathematical structures with differing characteristics, levels of complexity, and scientific purposes. The findings cover simple mechanical phenomena, oscillations, transportation, fluid dynamics, human activities, statistical modeling, and the development of instructional tools. Differences in model characteristics demonstrate that transforming phenomena into mathematical representations does not follow a single uniform equation structure or solution procedure. Akbar et al. (2021), Margaretta et al. (2019), and Tsai et al. (2022) demonstrated the use of mechanical principles as a foundation for formulation, whereas Obayashi et al. (2023) and Razzak et al. (2025) illustrated probabilistic and statistical approaches. Other studies, including Liang et al. (2021), Millah (2023), and Mao et al. (2021), demonstrated the application of mathematical models to systems with different physical characteristics and observation scales. This diversity provides the basis for

examining relationships among phenomenon characteristics, mathematical representations, solution methods, and the quality of model testing. The following discussion integrates these findings to answer the three research questions and explain their significance for developing the Fisika Campursari conceptual framework.

1. Characteristics and Classification of Mathematical Models of Everyday Physical Phenomena (RQ1)

The synthesis addressing RQ1 indicates that mathematical models of everyday physical phenomena can be classified along several interconnected dimensions: the nature of the phenomenon, the foundation of model construction, equation structure, system complexity, and the scientific function of the model. This finding is supported by Akbar et al. (2021), Margaretta et al. (2019), and Tsai et al. (2022), who used games and the mechanical behavior of simple objects as the foundations for developing mathematical models. Akbar et al. (2021) showed that rope motion during rope skipping can be explained using nonlinear differential equations involving rope tension, linear density, and rotational motion. Margaretta et al. (2019) demonstrated that the bending of an elastic column under its own weight can be analyzed using mechanical stability principles and scaling relationships. Meanwhile, Tsai et al. (2022) explained the motion of a stone skipping across a water surface by formulating hydrodynamic forces and changes in the state of motion during impacts. The three studies share the use of physical principles to establish mathematical relationships but differ in their dominant variables, equation forms, and predicted outputs. These differences demonstrate that phenomena that appear similarly simple can yield mathematical representations with distinct characteristics. Accordingly, models should not be classified solely by the objects observed; classification must also account for the physical mechanisms and mathematical structures used to represent system behavior.

Diversity in model characteristics is also apparent in transportation and fluid dynamics, which involve collective or multiscale changes in system states. Millah (2023) used the Lighthill–Whitham–Richards model to explain relationships among vehicle density, speed, and road conditions through a conservation-based approach. Putra and Gunawan (2018) applied kinematic equations and the finite volume method to represent queue formation and traffic shock waves. Unlike those studies, Saberi et al. (2020) employed an epidemic-analogy model to describe the propagation and reduction of congestion in urban networks. For fluid phenomena, Liang et al. (2021) developed a desorption equilibrium model to explain relationships among the water-to-coffee ratio, solute concentration, and extraction yield. Mo

et al. (2023) used particle hydrodynamics and microstructural characteristics to explain fluid transport through a porous coffee matrix. Yun (2017) analyzed liquid-droplet rebound dynamics by considering inertia, surface tension, and initial droplet geometry. Comparing these studies shows that mathematical representations can be differentiated by observation scale, forms of physical interaction, and the characteristics of changes in system states. Transportation phenomena are more commonly represented using continuum or network approaches, whereas fluid phenomena involve models ranging from equilibrium formulations and hydrodynamic approaches to dimensionless-parameter analyses.

Another classification dimension concerns the basis of model construction, particularly distinctions among mechanistic, empirical, and data-driven approaches. Mao et al. (2021) used an inverted pendulum model to estimate human walking parameters by simplifying a biomechanical system into a mechanical representation. Brink et al. (2023) developed a football-player dynamics model using ordinary differential equations with parameters obtained by fitting player-motion data. Obayashi et al. (2023) employed Gaussian mixture models to identify probabilistic relationships between paper-airplane geometry and flight trajectories. Meanwhile, Razzak et al. (2025) used the Weibull distribution to describe wind-speed variation through statistical parameters. These four studies used different mathematical approaches, although each sought to represent system behavior using determinable or observable variables. The model of Mao et al. (2021) was based on mechanistic simplification, whereas Brink et al. (2023) combined a motion-equation structure with data-driven parameter estimation. Obayashi et al. (2023) and Razzak et al. (2025) placed greater emphasis on statistical regularities and probabilistic relationships than on explicitly deriving every physical mechanism. These differences indicate that mathematical models may be oriented toward explanation or prediction, with their degree of physical interpretability depending on the basis of formulation and the characteristics of the data employed.

Classification by system complexity reveals further variations associated with linearity, the number of variables, and the characteristics of mathematical solutions. Pacala and Mendaño (2025) used the relationship between a simple pendulum's period and gravitational acceleration under the small-angle approximation. Habib and Pramudya (2021) investigated oscillations in two coupled pendulums, which produce in-phase and out-of-phase normal modes. Ramadhan and Novitrian (2026) employed Hamiltonian mechanics to analyze a double-pendulum system characterized by nonlinearity and sensitivity to initial conditions. These studies illustrate increasing representational complexity as the number of degrees of freedom, system interactions, and requirements for dynamical analysis increase. A simple

pendulum model allows physical quantities to be estimated using relatively direct mathematical relationships, whereas coupled pendulums require analysis of interactions between components. A double-pendulum system requires particular attention to numerical integration accuracy and the stability of physical properties throughout the simulation. These findings indicate that model complexity should be determined by the characteristics of the mechanisms and the objectives of analysis, rather than merely by the observable form of the phenomenon. System complexity is therefore a classification dimension that can be considered alongside phenomenon characteristics, the basis of formulation, and the model's scientific function.

The relationship between mathematical modeling and physics education is also evident in Muharam et al. (2024) and Sumardi et al. (2022). Muharam et al. (2024) used a simple rubber-powered car and the Tracker application to relate object motion to measurable kinematic parameters. Sumardi et al. (2022) developed an oscillation simulation in MATLAB to illustrate relationships between mathematical equations and the motion of a system. Both studies demonstrated how mathematical representations can be applied in experimental activities and the development of educational tools. However, developing instructional tools serves a different purpose from research specifically intended to develop or test new theoretical models. This distinction must be retained in the classification to avoid conflating the characteristics of mathematical models with the types of applications in which they are employed. Taken together, the answer to RQ1 is that mathematical modeling of everyday physical phenomena has multidimensional characteristics that can be grouped according to phenomena, sources of formulation, mathematical forms, complexity, scientific functions, and application contexts. The significance of this finding lies in establishing a classification structure that allows studies of different phenomena to be compared using common analytical dimensions. From the Fisika Campursari perspective, this classification provides a conceptual basis for organizing diverse everyday phenomena as subjects of physics modeling without overlooking the distinctive characteristics of each system.

2. Formulation, Solution Methods, Validation Strategies, and Limitations of Mathematical Models (RQ2)

The analysis addressing RQ2 indicates that mathematical formulation approaches in previous studies can be distinguished as derivations from physical principles, adaptations of theoretical models, empirical simplifications, and data-driven model construction. Akbar et al. (2021) used principles of rope mechanics to derive nonlinear differential equations describing

changes in rope shape during a game. Tsai et al. (2022) constructed a formulation by identifying forces and dividing the motion of a stone on water into several stages. Liang et al. (2021) employed a desorption equilibrium approach to simplify coffee brewing processes involving various dissolved components. These studies show that model formulation begins by identifying dominant mechanisms and selecting variables that represent the phenomenon's characteristics. Meanwhile, Mao et al. (2021) and Pacala and Mendaño (2025) used established mechanical models to estimate physical quantities from observational data. Obayashi et al. (2023) adopted a different approach by constructing probabilistic relationships between paper-airplane geometry and flight outcomes based on testing. This comparison illustrates that formulations may originate from physical laws, existing models, or relationships identified from data. Clarifying the origin of a formulation is therefore essential to explaining the relationship between a mathematical model and the phenomenon it represents.

A further finding concerns the use of mathematical simplification to develop models that permit analytical solutions. Akbar et al. (2021) showed that nonlinear equations of rope motion can be solved analytically under small-deflection conditions. However, as deflections increase, numerical solutions become necessary to represent rope profiles under more general conditions. Margaretta et al. (2019) used elastic mechanics and scaling analysis to explain changes in the configuration of a slender column under its own weight. Liang et al. (2021) used a mean equilibrium constant to represent coffee extraction processes involving various chemical components. All three studies applied simplifications to establish mathematical relationships capable of explaining particular system characteristics. Nevertheless, each simplification has consequences for the range of conditions that the model can describe. A small-deflection approximation does not directly capture all nonlinear behavior, whereas an equilibrium model does not necessarily represent the complete transient process. The synthesis therefore indicates that simplification should be understood as part of model construction and expressed through clearly stated assumptions and domains of validity.

A comparison of solution methods shows that numerical approaches are used when model equations exhibit nonlinear characteristics, particular boundary conditions, or complexity that makes analytical solutions difficult. Millah (2023) employed an upwind method to solve a traffic-flow model, whereas Putra and Gunawan (2018) applied the finite volume method to represent changes in vehicle density. Tsai et al. (2022) used numerical solutions to estimate stone trajectories and the number of skips across a water surface. Mo et al. (2023) combined microstructural information with particle-based hydrodynamic simulations to explain fluid

motion in porous media. Ramadhan and Novitrian (2026) extended this comparison by examining the Runge–Kutta, Störmer–Verlet, implicit midpoint, and Gauss–Legendre methods for a double-pendulum system. Their study demonstrated that different algorithms may produce different energy-stability and numerical-error characteristics, even when applied to the same physical system. These findings confirm that obtaining numerical outputs cannot automatically be equated with preserving the physical properties of a model. Their significance lies in the need to distinguish the correctness of model formulation from the reliability of the algorithm used to solve it. Mathematical model evaluation should therefore consider equation structure, the appropriateness of computational methods, numerical-error characteristics, and the consistency of results with physical principles.

Empirical validation strategies vary in their use of instruments, measurements, and comparisons with reference values. Pacala and Mendaño (2025) compared estimates of gravitational acceleration obtained through traditional measurements and Tracker video analysis, reporting values of 9.9 ± 1.8 m/s² and 10.0 ± 0.9 m/s², respectively. Habib and Pramudya (2021) compared coupled-pendulum oscillation characteristics based on theoretical results, an ultrasonic sensor, and the Tracker application. They reported measurement errors of approximately 18.4% using Tracker and 12.55% using the ultrasonic sensor. Mao et al. (2021) used an optical motion capture system as a reference for evaluating estimates of human walking parameters obtained from an inverted pendulum model. The study reported correlations exceeding 0.9 for several parameters and a mean step-length bias of approximately 0.006 m under the tested conditions. These studies indicate that comparing model outputs against measurements provides information about the agreement between mathematical predictions and observed physical quantities. However, the quality of such comparisons remains influenced by instrument characteristics, measurement procedures, experimental conditions, and the comparability of the quantities examined. Agreement between predicted and measured values must therefore be accompanied by consideration of uncertainty and the limits of data representativeness.

Testing strategies in fluid and transportation phenomena reveal differences between validation using direct observations and evaluation based on simulation behavior. Liang et al. (2021) compared equilibrium-model predictions with coffee-brewing experiments and reported a relatively constant extraction yield of approximately 21% under the tested conditions. Tsai et al. (2022) compared simulated stone trajectories with experimental observations to assess the formulation's ability to describe the motion process. Yun (2017) used experimental measurements to analyze relationships among droplet geometry, contact

time, and rebound characteristics on superhydrophobic surfaces. By contrast, Millah (2023) and Putra and Gunawan (2018) primarily demonstrated traffic-model behavior under various numerical simulation scenarios. Saberi et al. (2020) used transportation-network data from six cities to examine the representation of congestion propagation and reduction. These differences show that physical modeling studies may have varying levels and types of empirical support. Tests based on hypothetical scenarios primarily provide information about a model's mathematical behavior under specified conditions, whereas comparisons with observational data provide evidence about its agreement with measured phenomena. Conclusions regarding model validity must therefore reflect the actual testing procedures and the conditions represented by the research data.

Differences in evaluation strategies are also evident in studies developing instructional and simulation tools. Muharam et al. (2024) developed a rubber-powered car experiment using Tracker and reported a mean student response of 71.63%. Sumardi et al. (2022) developed an oscillation simulation tool using MATLAB and obtained suitability ratings predominantly in the good to very good categories. Razzak et al. (2025) developed a spreadsheet-based wind-speed distribution simulator to generate distribution curves and explore statistical parameters. These studies illustrate the application of mathematical representations in developing tools for exploring phenomena. However, a tool's ability to produce visualizations or obtain favorable user responses is a different outcome from assessing model accuracy against physical data. This distinction matters because indicators of instructional suitability do not directly measure mathematical prediction errors or the explanatory strength of a mechanistic model. Overall, the answer to RQ2 is that modeling quality depends on the suitability of the formulation to the phenomenon, the accuracy of the solution method, the adequacy of the testing strategy, and the clarity of the model's domain of applicability. The significance of this result lies in establishing an evaluative basis that distinguishes theoretical consistency, numerical accuracy, empirical validation, and suitability for use as components serving different testing purposes. Within the Fisika Campursari perspective, this distinction provides a foundation for assessing modeling research outputs without treating all forms of testing as evidence of equivalent strength.

3. Conceptual Patterns, Research Gaps, and Modeling Principles within the Fisika Campursari Framework (RQ3)

The synthesis addressing RQ3 identified a conceptual pattern in which everyday phenomena are transformed into mathematical representations through several interconnected

components. These include observing phenomena, identifying physical mechanisms, selecting variables and parameters, establishing assumptions, mathematical formulation, solution, testing, and interpretation of results. Akbar et al. (2021) illustrated this sequence through the modeling of rope motion, starting from mechanical characteristics and culminating in a nonlinear differential equation. Margaretta et al. (2019) used the bending of an elastic object to develop a mathematical representation of stability and scaling relationships. Tsai et al. (2022) connected observations of stone skipping with force identification, subdivision of motion into stages, and numerical solutions. Liang et al. (2021) used coffee brewing to develop an equilibrium model that was subsequently compared against experimental data. These common processes demonstrate the recurrence of modeling components despite differences in phenomena, equation forms, and solution approaches. However, the recurring components are not necessarily applied in an identical order, because data-driven studies may begin formulation by identifying empirical regularities. Therefore, the synthesized conceptual pattern is more appropriately understood as a network of interrelated analytical components than as a mandatory linear procedure that applies identically to all physical phenomena.

Another pattern concerns the relationship between simplifying mechanisms and selecting the mathematical characteristics needed to explain a phenomenon. Akbar et al. (2021) employed a small-deflection approximation to obtain an analytical relationship for a system that is nonlinear under more general conditions. Margaretta et al. (2019) adopted a slender elastic-column approximation to analyze changes in an object's configuration due to gravity. Liang et al. (2021) used an averaged equilibrium representation of coffee extraction, which in reality involves numerous components. Mao et al. (2021) employed an inverted pendulum as a simplified representation of the human biomechanical system. These four studies demonstrate that abstraction involves selecting mechanisms and parameters relevant to modeling objectives. Nevertheless, the simplifications employed restrict the model's applicability to phenomena that differ from the initial assumptions. This finding underpins the principle of representational adequacy: a model should preserve the physical characteristics necessary to explain the target variables without reproducing the system's full complexity. Within the Fisika Campursari framework, this principle links the observation of everyday phenomena to the selection of physical quantities and mathematical relationships that can be scientifically tested.

A further conceptual pattern is the use of mathematical analogies to connect phenomena with different dynamical characteristics. Margaretta et al. (2019) employed scaling relationships

and an analogy with second-order phase transitions to explain the bending of an elastic column under its own weight. Akbar et al. (2021) identified scaling characteristics in changes to rope profiles associated with critical behavior in mechanical systems. Saberi et al. (2020) employed a mathematical structure inspired by epidemic dynamics to represent the propagation of congestion across transportation networks. These studies illustrate the use of mathematical relationships also encountered in other physical phenomena or dynamical systems. However, similar mathematical structures do not automatically imply equivalence in mechanisms or parameter interpretation across the phenomena being compared. The phase-transition analogy for elastic bending must be limited to mathematical characteristics that are genuinely comparable. Likewise, the epidemic-analogy model of traffic congestion has limitations when road conditions allow congestion to recur after initially decreasing. Therefore, the principle of transferring representations within the Fisika Campursari framework must include assessments of variable correspondence, assumptions, mathematical relationships, and the model's domain of validity. This finding is important for preventing analogies based solely on similarities in equation form without considering the physical characteristics of the systems.

The identified research gaps primarily concern the fragmentation of studies across phenomenon groups, formulation types, and model evaluation strategies. Akbar et al. (2021), Margaretta et al. (2019), and Tsai et al. (2022) investigated games and simple mechanics with differing analytical orientations. Millah (2023), Putra and Gunawan (2018), and Saberi et al. (2020) focused on transportation systems through continuum and network dynamics approaches. Liang et al. (2021), Mo et al. (2023), and Yun (2017) examined fluid and mass-transfer phenomena using different levels of representation. Meanwhile, Mao et al. (2021), Brink et al. (2023), and Obayashi et al. (2023) illustrated variations in modeling human activities and manufactured objects. These studies provide insights into their respective phenomena, but within the reviewed corpus they do not jointly present a cross-phenomenon classification based on shared analytical categories. This fragmentation provides a rationale for integrating phenomenon characteristics, formulation approaches, solution methods, and validation strategies within a single analytical structure. However, the identified gap should not be interpreted as evidence that no previous research has developed a comparable conceptual framework. The claim is confined to comparisons among the 18 articles analyzed in this study.

Based on these conceptual patterns, the Fisika Campursari framework was synthesized as a structure connecting contextual phenomena with the construction and evaluation of

mathematical models. The phenomenon-identification stage involves selecting everyday events that exhibit physical mechanisms and permit quantitative observation. The identification of physical principles involves selecting relevant laws of motion, conservation relationships, material properties, fluid characteristics, or statistical relationships. Abstraction entails determining variables, parameters, assumptions, and observation scales. Mathematical formulation is then expressed through equations or functions appropriate to the mechanisms and objectives of the model. Solutions may be obtained through analytical or numerical methods or through data-driven parameter estimation. Testing involves checking theoretical consistency, conducting numerical evaluations, or comparing outputs against empirical data, according to the characteristics of the study. The final stage involves interpreting outputs and defining the model's domain of validity, with the possibility of revising assumptions or parameters. This framework is a conceptual construct developed from common components found in previous studies, rather than the result of empirically validating a universal model. Thus, the answer to RQ3 is that cross-phenomenon patterns of mathematical modeling can be synthesized into relationships among observation, abstraction, formulation, solution, testing, and interpretation that constitute the principal components of the Fisika Campursari conceptual framework.

4. Significance of the Findings and Contributions to the Discipline

The primary significance of this study lies in integrating mathematical modeling findings from diverse physical phenomena that had been discussed separately within the reviewed corpus. Akbar et al. (2021) and Margaretta et al. (2019) demonstrated relationships between simple phenomena and nonlinear mathematical characteristics and scaling behavior. Tsai et al. (2022) and Liang et al. (2021) illustrated links between mechanistic formulations and experimental testing. Millah (2023), Putra and Gunawan (2018), and Saberi et al. (2020) extended the scope of modeling to transportation systems involving collective dynamics. Mao et al. (2021), Brink et al. (2023), and Obayashi et al. (2023) contributed to modeling human movement and manufactured objects through mechanistic and data-driven approaches. Integrating these findings yielded a comparative structure covering phenomenon characteristics, formulation foundations, solution methods, and model evaluation. Within physics, this structure can be used to understand relationships between the mechanisms underlying phenomena and the mathematical representations selected to explain them. The contribution is conceptual and methodological because the study does not develop a new equation for a particular phenomenon. Its significance therefore lies not in discovering a

universal physical law, but in providing a structured synthesis of how different modeling approaches are applied, compared, and evaluated.

A further contribution concerns clarifying the conceptual distinctions among a model's ability to explain mechanisms, generate predictions, and support learning activities. Pacala and Mendaño (2025) and Habib and Pramudya (2021) demonstrated the use of experiments to compare mathematical relationships with measurable physical quantities. Ramadhan and Novitrian (2026) emphasized the evaluation of numerical stability in a system with nonlinear characteristics. Muharam et al. (2024) and Sumardi et al. (2022) showed how mathematical representations can be used to design experiments and develop instructional tools. These different orientations indicate that modeling success may be reported using different indicators depending on research objectives. This synthesis contributes a conceptual separation among physical validity, numerical accuracy, predictive capability, and pedagogical suitability. From the Fisika Campursari perspective, this distinction is important for using everyday phenomena as sources of physics inquiry without conflating scientific explanatory objectives with educational objectives. Consequently, this study provides a foundation for contextual modeling research that maintains clarity regarding assumptions, testing procedures, and the domains of model validity.

5. Theoretical, Methodological, and Practical Implications

The theoretical implications of this study concern the formulation of Fisika Campursari as an integrative conceptual framework that places everyday phenomena at the starting point of physics inquiry through mathematical modeling. Akbar et al. (2021), Margaretta et al. (2019), and Tsai et al. (2022) demonstrated that simple activities can be used to identify mechanisms and mathematical relationships with considerable analytical depth. Liang et al. (2021) and Mo et al. (2023) showed that activities related to coffee brewing can be analyzed at different observation scales and levels of complexity. These findings provide opportunities to organize contextual phenomena through relationships among dominant mechanisms, representational structures, and modeling objectives. Methodologically, the synthesized framework can serve as a basis for establishing analytical categories in subsequent studies of everyday-phenomenon modeling. These categories may include phenomenon characteristics, variables, assumptions, mathematical formulations, solution methods, testing strategies, and limitations of model applicability. Consistent categories enable researchers to compare models with different scientific purposes without imposing a single common indicator of success.

Nevertheless, applying the framework in new research still requires adaptation to the physical mechanisms and conditions of the phenomena under investigation.

The practical implications concern the use of everyday phenomena as sources of observation, experimentation, and mathematical exploration in physics education. Muharam et al. (2024) demonstrated the use of a simple rubber-powered car and Tracker to observe kinematic parameters through designed experimental activities. Sumardi et al. (2022) illustrated the use of MATLAB simulations to represent oscillatory phenomena in instructional tools. Razzak et al. (2025) developed a spreadsheet simulator that allows users to explore relationships between statistical parameters and the characteristics of wind-speed distributions. These studies provide examples of applying mathematical representations through tools for visualizing and exploring phenomena. In the context of Fisika Campursari, the synthesis can provide a conceptual foundation for designing activities that proceed from observation and identification of physical quantities to model construction and verification of results. Such activities can connect contextual experience with physics analysis procedures in a more structured way. However, the potential educational application of this framework cannot be treated as evidence of improved conceptual understanding, modeling skills, or student learning outcomes. Its pedagogical effectiveness requires separate testing using appropriate instruments and research designs.

6. RESEARCH LIMITATIONS

This study has limitations related to the scope of the literature and the characteristics of the available evidence. The corpus comprised 18 articles published between 2017 and 2026, encompassing diverse physical phenomena and modeling approaches. Although this number and diversity were sufficient to develop a classification and identify conceptual patterns within the corpus, they do not ensure that all developments in mathematical modeling of everyday phenomena are represented. The available document also lacked a complete literature-search history, including databases, keyword combinations, search dates, initial article counts, and reasons for exclusion at each selection stage. This documentation gap limits assessments of search reproducibility and the risk of selection bias. Furthermore, the reviewed studies employed different designs, instruments, outcome variables, and validation strategies; their quantitative findings could therefore not be directly combined into a single measure of model effectiveness. Some studies prioritized experiments, whereas others employed simulation, theoretical analysis, or evaluation of instructional tools. Accordingly, this synthesis is primarily descriptive qualitative and comparative rather than a quantitative

meta-analysis. The findings should be interpreted as patterns identified in the selected literature, not as statistical generalizations to all mathematical modeling research.

A further limitation concerns the conceptual status of the Fisika Campursari framework derived from the literature synthesis. The framework integrates the observation of phenomena, identification of physical mechanisms, abstraction, formulation, solution, testing, and model interpretation based on the characteristics of previous studies. However, the framework has not been empirically tested as a complete procedure across diverse types of physical phenomena. Akbar et al. (2021), Margaretta et al. (2019), Tsai et al. (2022), and Liang et al. (2021) support particular modeling components but do not directly test the entire synthesized framework proposed in this study. Differences between mechanistic and data-driven approaches also limit the feasibility of using a single identical formulation procedure for every model. In addition, the variation in validation strategies across the corpus means that the level of empirical support for each model is not fully comparable. This study also did not test how the Fisika Campursari framework affects mathematical modeling ability or the understanding of physics concepts in educational contexts. Its contribution is therefore limited to developing an analytical structure and conceptual principles traceable to the reviewed literature. Further research is required to examine the consistency of applying the framework to different phenomena, evaluate the adequacy of its components, and test its benefits using empirical data.

7. FINAL SYNTHESIS OF THE DISCUSSION

Taken together, the three research questions yielded complementary findings regarding the characteristics and processes of mathematical modeling of everyday physical phenomena. The answer to RQ1 shows that mathematical models can be classified according to phenomena, sources of formulation, equation structure, complexity, and scientific function. The answer to RQ2 indicates that formulation, solution, and validation are interrelated methodological components with distinct bases of evaluation. The answer to RQ3 identifies a conceptual pattern linking contextual phenomena with the identification of physical principles, abstraction, mathematical representation, solution, testing, and interpretation of results. Akbar et al. (2021), Margaretta et al. (2019), Tsai et al. (2022), and Liang et al. (2021) provide examples of the relationship between everyday phenomena and the construction of mathematical models. Millah (2023), Putra and Gunawan (2018), Saberi et al. (2020), and Mo et al. (2023) extend the scope of representations to more complex transportation and fluid systems. Mao et al. (2021), Brink et al. (2023), Obayashi et al. (2023), Pacala and Mendaño

(2025), Habib and Pramudya (2021), and Ramadhan and Novitrian (2026) broaden our understanding of mechanistic and data-driven approaches, measurement, and numerical evaluation. Meanwhile, Muharam et al. (2024), Sumardi et al. (2022), and Razzak et al. (2025) demonstrate applications of mathematical representations through experimental and simulation tools. Integrating these findings yielded a Fisika Campursari conceptual framework that positions everyday phenomena as sources of physics inquiry based on mathematical modeling. The study's primary contribution lies in establishing a multidimensional classification, distinguishing model testing strategies, and organizing cross-phenomenon conceptual relationships that may provide a foundation for further research.

CONCLUSIONS AND RECOMMENDATIONS

Based on a systematic literature review of 18 scientific articles published between 2017 and 2026, this study concludes that mathematical modeling of everyday physical phenomena exhibits multidimensional characteristics that can be classified by phenomenon type, formulation approach, equation structure, degree of complexity, and the scientific function of the model. The phenomena examined include mechanics and games, oscillations, transportation, fluid dynamics, human activities, and environmental and educational phenomena. The mathematical models identified include mechanistic, phenomenological, statistical, and data-driven approaches represented by algebraic equations, differential equations, equilibrium models, scaling relationships, and probability distributions. This diversity indicates that the characteristics of mathematical representations depend on physical mechanisms, simplifying assumptions, and modeling objectives. The findings also demonstrate that formulation and solution approaches are closely related to testing strategies and the domains in which models remain valid. Model validation in the literature encompasses checks of theoretical consistency, numerical evaluation, empirical comparison, and assessment of instructional-tool usability, each with different indicators of success. Accordingly, the classification and evaluation of mathematical models should consider the appropriateness of their formulation, the accuracy of solution methods, the adequacy of testing evidence, and limitations on their applicability.

The main finding of this study is the synthesis of a Fisika Campursari conceptual framework that systematically integrates everyday phenomena with physical principles and mathematical modeling processes. The framework encompasses phenomenon identification, determination of physical mechanisms, abstraction and simplification, mathematical formulation, model solution, testing of results, interpretation, and determination of domains of validity. The

synthesis reveals conceptual links among these stages even though previous studies used different approaches and mathematical structures. The theoretical contribution lies in organizing modeling characteristics across phenomena into a conceptual structure that allows consistent comparison. The methodological contribution consists of integrating model classification, formulation approaches, solution methods, and validation strategies as complementary analytical dimensions. In physics and physics education, the framework provides a conceptual foundation for making everyday phenomena subjects of scientific inquiry by connecting observation, physical reasoning, and mathematical representation. However, the framework remains a conceptual construct based on selected literature and has not yet been empirically validated as a modeling procedure applicable to all physical phenomena.

Future research should expand the literature base through a systematically documented search strategy to strengthen the representativeness of the evidence and the reproducibility of the selection process. Subsequent development should include expert validation of the framework's structure, relationships among components, and the clarity of its modeling principles. Empirical studies applying the framework to various contextual physical phenomena are also needed to assess the consistency of abstraction procedures, the accuracy of formulations, and agreement between model outputs and observations. Such testing may compare analytical, numerical, and data-driven models using indicators of error, measurement uncertainty, and solution stability appropriate to the model's objectives. In physics education, future studies could develop and evaluate Fisika Campursari-based instructional tools to examine their effects on conceptual understanding, mathematical modeling abilities, and problem-solving skills. Further research should also investigate the limitations of applying the framework to nonlinear phenomena, multiscale systems, and events involving interactions among multiple physical mechanisms. Through these developments and tests, the Fisika Campursari conceptual framework is expected to acquire a stronger validation basis and make a measurable contribution to the development of contextual physics modeling methodology and research in physics education.

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