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Computational Modeling and Video Analysis in Kinematics Learning: A Systematic Review of Tracker Software Use in Physics Laboratories

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ABSTRACT

Tracker, a free video analysis and modeling tool, is widely used in physics laboratories, yet it is unclear what the evidence shows about its effects on kinematics learning and how its video analysis and modeling functions are combined. This systematic review, reported with reference to PRISMA 2020, addressed two questions: (1) how Tracker-based learning designs are used to support conceptual understanding and address misconceptions in kinematics, and what outcomes are reported; and (2) how video analysis is integrated with computational modeling to improve laboratory experimental design. Peer-reviewed journal articles published between 2016 and 2026 were screened, appraised with the Mixed Methods Appraisal Tool, and synthesised thematically. Three of the eight studies listed in the initial draft did not meet the eligibility criteria, and one entry could not be verified. The working corpus comprised twelve studies: seven reporting learner outcomes and five reporting measurement validity or instructional design. Most studies were conducted in Indonesian secondary schools and used one-group or non-equivalent designs. Reported outcomes included gains in science process skills (N-gain = 0.53), graph interpretation (N-gain = 0.68), investigative skills, creative thinking (N-gain = 0.20), and critical thinking. Measurement studies showed that Tracker produced kinematic parameters consistent with theoretical values, such as g = 9.98 m/s². However, only one study examined conceptual understanding with a diagnostic approach, none used standardised instruments such as the Test of Understanding Graphs in Kinematics, and none explicitly reported using Tracker's dynamic modeling feature. The claims that Tracker remediates misconceptions and that combining video analysis with modeling yields larger gains are therefore plausible, supported by earlier international studies, but not yet established by the 2016–2026 evidence. The review proposes a five-level framework for integrating video analysis and modeling, together with an inquiry-based laboratory design and a research agenda.

Keywords: Video Analysis; Computational Modeling; Kinematics; Misconceptions; Inquiry-Based Laboratory

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I. INTRODUCTION

Kinematics is the entry point to learning mechanics, yet physics education research shows that the topic harbors persistent difficulties. Secondary and university students often confuse position with velocity and the slope of a graph with its height, and they tend to treat graphs as pictures of the path of motion. These difficulties become apparent when students are asked to connect graphs with physics concepts and with the real world (McDermott et al., 1987). The Test of Understanding Graphs in Kinematics (TUG-K) was developed to measure these difficulties in a standardized way and showed that errors in interpreting kinematics graphs are widespread (Beichner, 1994). In Indonesia, a systematic review of kinematics misconceptions identified rectilinear motion as the main area of misconception, with most misconceptions originating from students' preconceptions, faulty intuitions, and reasoning patterns (Rahmadani et al., 2023).

Laboratories occupy a special position in addressing these difficulties because they allow students to connect phenomena, data, and theory. However, a classic review of science laboratories cautions that laboratory activities are often procedural and do not by themselves produce conceptual understanding (Hofstein & Lunetta, 2004). Technologies that display motion data directly have long been studied as a way to bridge this gap. Microcomputer-based laboratories that display motion graphs in real time were shown to help students understand motion concepts (Thornton & Sokoloff, 1990). Video motion analysis has likewise been found to improve students' ability to interpret kinematics graphs, with larger gains

when the tool was integrated more deeply into the curriculum and used directly by students rather than merely demonstrated by the teacher (Beichner, 1996).

Tracker, open-source software from the Open Source Physics project, combines two functions in a single environment: video analysis and modeling. Brown and Cox (2009) described how Tracker enables users to track objects in a video while building models that can be compared directly with the recorded motion. Wee et al. (2012) used this combination for projectile motion, allowing students to test their hypotheses by juxtaposing their mental models against the analysis of real-life videos and to address common misconceptions. Hockicko et al. (2014) showed that university students' estimates of car braking distances contained systematic rather than random errors, indicating misconceptions. These errors decreased after students watched braking videos, and some students analyzed real cases using Tracker. Stronger evidence comes from cluster-randomized trials using a different video analysis application on tablets. Among 286 secondary school students in Germany, this approach reduced extraneous cognitive load and improved conceptual understanding of reference frames (Becker et al., 2020a), and the effects were subsequently replicated for two kinematics subconcepts (Becker et al., 2020b).

Theoretically, Tracker-based learning can be explained through several complementary frameworks. *First*, the inquiry framework places students in a cycle of orientation, conceptualization, investigation, conclusion, and discussion (Pedaste et al., 2015). A meta-analysis showed that guided inquiry has positive effects on learning outcomes ($d = 0.50$), performance success, and learning activities (Lazonder & Harmsen, 2016). *Second*, conceptual change theory holds that a new conception is accepted when learners become dissatisfied with their existing conception and the new one appears intelligible, plausible, and fruitful (Posner et al., 1982). Comparing videos with students' predictions can potentially trigger such dissatisfaction. *Third*, the framework of learning with multiple representations explains that video, trajectories, tables, graphs, and equations can complement one another, constrain interpretation, and build deeper understanding, provided that students are supported in translating between representations (Ainsworth, 2006). *Fourth*, modeling theory in physics instruction places the construction and validation of models at the core of scientific activity (Hestenes, 1987). Finally, social constructivism emphasizes that cognitive development is mediated by interaction with more competent others within the zone of proximal development (Vygotsky, 1978).

In Indonesia, publications on Tracker have grown rapidly. A review of 25 Scopus articles found that physics education and mechanics dominated Tracker applications, and that the share of articles increased from 43.5% in the pre-pandemic period (2016–2019) to 56.5% in 2020–2023, in line with the need for remote laboratory work (Nisa et al., 2024). That review, however, focused on mapping usage trends rather than on the quality of evidence regarding learning outcomes. Three gaps follow from this. The *empirical* gap concerns whether studies published in 2016–2026 demonstrate improvements in conceptual understanding and kinematics misconceptions using adequate designs and instruments. The *conceptual* gap concerns the lack of distinction between levels of integration of video analysis and modeling, even though the modeling function is what distinguishes Tracker from ordinary video tracking tools. The *methodological* gap concerns the possibility that claims of effectiveness rest on one-group designs without comparison groups.

This review addresses two research questions (RQs). RQ1: How are Tracker-based learning designs used to support conceptual understanding and address misconceptions in kinematics, and what outcomes are reported, with what strength of evidence? RQ2: How is video analysis integrated with computational modeling in the use of Tracker to improve laboratory experimental design? The review makes three contributions: (1) it evaluates the strength of evidence for each effectiveness claim; (2) it proposes a five-level framework of video–model integration as an analytical and design tool; and (3) it formulates

an inquiry-based laboratory design and a testable research agenda. Because no effect sizes were pooled, this study is not a meta-analysis; nor does it address quantum physics, since none of the included studies examined that domain.

II. RESEARCH METHODS

This study is a systematic review with narrative–thematic synthesis, reported in accordance with PRISMA 2020 (Page et al., 2021). A meta-analysis was not conducted because most studies did not report the statistics required to compute standardized effect sizes, and their designs, outcomes, and instruments were highly heterogeneous.

The eligibility criteria are summarized in Table 1. Kinematics was defined broadly as the description of motion through position, velocity, and acceleration as functions of time, including oscillatory motion analyzed through kinematic graphs. This definition is stated explicitly because the preliminary list included simple pendulum studies without specifying the topical boundary. Measurement-validation studies conducted for instructional purposes were included but coded separately from studies reporting learning outcomes.

Table 1. Eligibility criteria

Aspect	Inclusion Criteria	Exclusion Criteria
Participants	Secondary school students, undergraduate students, or pre-service physics teachers	Studies without learner participants, except measurement-validation studies conducted for instructional purposes
Intervention/tool	Use of the Tracker software (Open Source Physics) for video analysis and/or modeling	Other video analysis applications or simulations without video; used as contextual evidence
Topic	Rectilinear motion, free fall, projectile motion, circular motion, and oscillatory motion analyzed kinematically	Rotational dynamics, fluids, optics, or other topics without kinematic analysis
Outcomes	Conceptual misconceptions, measurement accuracy, or experimental design	-
Publication type	Peer-reviewed journal articles, 2016–2026, in Indonesian or English	Conference proceedings, theses, book chapters, articles without full text; literature reviews used as contextual evidence

The preliminary search relied solely on Google Scholar. An evaluation of 28 academic search systems showed that Google Scholar is inadequate as a principal source for systematic reviews, partly because of limited query precision and poor reproducibility of results (Gusenbauer & Haddaway, 2020). The search was therefore conducted in Scopus, ERIC, and DOAJ, with Google Scholar and Garuda used as supplementary sources to reach national journals. The search was performed in June 2026 using the string: (“Tracker” OR “video tracker” OR “video analysis”) AND (kinematic∗ OR motion OR “free fall” OR projectile OR pendulum) AND (physics) AND (student∗ OR learning OR laboratory). The Indonesian equivalent was (“Tracker” OR “analisis video”) AND (kinematika OR gerak OR praktikum). The search was complemented by snowballing through the reference lists of the included studies.

Two reviewers independently screened titles and abstracts and then assessed full texts. Agreement was calculated using Cohen’s kappa. The eight entries on the preliminary list were re-verified against the publishers’ websites, and the results are reported in Table 3. A qualitative CASP checklist was initially considered; however, because the corpus was dominated by non-randomized quantitative and descriptive designs, quality was appraised using the Mixed Methods Appraisal Tool (MMAT) version 2018, which provides criteria for different study designs within a single framework (Hong et al., 2018).

Data were extracted using a form that captured study identification, educational level, topic, design, sample, instruments, Tracker features used, level of video–model integration, and findings. The synthesis followed a thematic synthesis approach that moves from coding findings to descriptive themes and then to analytical themes (Thomas & Harden, 2008). Coding followed the six phases of thematic analysis (Braun & Clarke, 2006) and was conducted reflexively, acknowledging the interpretive role of the researchers (Braun & Clarke, 2019).

Table 2. Summary of the PRISMA 2020 selection process

PRISMA 2020 stage	Number	Remarks
Records identified from data base	23	Search date: June 2026
Duplicates removed	3	Identified using the Mendeley reference manager
Records screened (title/abstract)	20	Excluded: 4
Full-text reports assessed	16	Excluded with reasons: outside the publication period (1), conference proceedings (1), review (1), unverifiable (1), topic outside kinematics
Studies included	12	Learning outcomes: 7; measurement validity/design: 5

Table 3. Verification of the eight entries on the preliminary list

Preliminary-list entry	Verification result	Decision
Raflesiana et al. (2019)	The title belongs to Habibbulloh and Madlazim (2014)	Excluded: published outside 2016–2026).
Nisa et al. (2024)	Systematic review of 25 Scopus articles	Excluded from the corpus; used as contextual evidence
Wati et al. (2020)	Journal of Physics: Conference Series	Excluded: conference proceedings
Renika et al. (2024)	Verified	Included (S6)
Nadia et al. (2025)	The title belongs to Putri (2023);	Included with corrected metadata (S10)
Handayani et al. (2022)	Verified	Included (S8)
Fitriyanto (2016)	Verified; pre-experimental design	Included (S1)
Yuberti et al. (2020)	DOI refers to a different article	Excluded: unverifiable.

Table 4. Coding framework

Code Category	Operational Definition	Source Of The Framework
Instructional design	Guided inquiry, STEM, blended learning, conventional laboratory work supported by Tracker.	Inquiry phases (Pedaste et al., 2015)
Level of video–model integration	L0–L4 (Table 7): from visualization to student-built computational models	Brown & Cox (2009); Hestenes (1987)
Representations	Video, trajectory/stroboscopic view, data table, x–t/v–t/a–t graphs, model equations	Ainsworth (2006)
Conceptual outcomes	Conceptual understanding, misconceptions, graph interpretation; type of instrument	Beichner (1994); Posner et al. (1982)
Skill outcomes	Science process, investigative, critical, creative, and computational thinking skills	Weintrop et al. (2016)
Measurement validity	Agreement between measured and theoretical/reference values; sources of error	Inductive

III. RESULTS AND DISCUSSION

The working corpus consisted of twelve studies (Table 5). Seven studies reported learning outcomes (S1–S7), and five reported measurement validity or instructional design (S8–S12). All studies were conducted in the Indonesian context; eleven were published in national journals and one (S12) in an international journal. The predominant educational level was senior high school (SMA/MA), followed by junior high school (SMP). The most frequently studied topics were uniformly accelerated

motion, free fall, projectile motion, and oscillatory motion. Of the seven outcome studies, only two used a comparison group (S2 and S7), and in S7 the two groups came from different grade levels. Four studies used one-group or descriptive designs (S1, S3, S4, S5), whereas the design and sample of S6 could not be fully determined from the information available and require confirmation from the full text.

Table 5. Characteristics of the included studies

Code	Study	Context	Design and sample	Main findings
A. Studies reporting learning outcomes				
S1	Fitriyanto & Sucahyo (2016)	Senior high school, grade XI; rectilinear and projectile motion	Pre-experimental one-group pretest–posttest; expert validation (3 validators)	N-gain in science process skills of 0.53 (medium); feasibility of the projectile motion practicum 91.67% (very good)
S2	Artiningsih & Nurohman (2019)	JHS, grade VIII; uniformly accelerated motion	Quasi-experimental nonrandomized pretest–posttest control group design.	Positive effect on investigative skills (t-test, sig. = 0.024); the control group used PowerPoint and video
S3	Raflesiana et al. (2019)	SHS, grade X; harmonic motion, guided inquiry	One-group pretest–posttest; paired t-test	Graph interpretation scores increased by 58.64%; N-gain = 0.68; $p < .05$
S4	Amaliah et al. (2020)	Senior high school, grade X; motion concepts	Descriptive; multiple-choice pretest–posttest with CRI and interviews; n = 30	Initially low conceptual understanding, which improved after video-based learning with Tracker
S5	Alfayani et al. (2024)	SHS, grade X; harmonic motion, guided-inquiry.	One-group pretest–posttest; n = 36	N-gain in creative thinking of 0.20 (low), although the pre–post difference was significant
S6	Renika et al. (2024)	Laboratory work on free fall and inclined planes	Experimental and descriptive quantitative	Acceptable errors; graphs consistent with theory; air resistance affected acceleration
S7	Zaina et al. (2026)	Islamic SHS, accelerated motion, STEM learning	Quasi-experimental; grade XI science (experimental) vs. grade X A (control)	Significant pre–post difference in the experimental group ($p < .05$); effect size = 1.82. The groups came different grade
B. Measurement validity and instructional design studies				
S8	Handayani et al. (2022)	Online laboratory work; simple pendulum	Measurement experiment; survey of 30 respondents	Mean g = 9.98 m/s²; respondent-rated effectiveness score of 83.83%
S9	Handayani et al. (2023)	Laboratory work; spring constant and pendulum	Video analysis to determine physical constants	Values of g and the spring constant were derived from graphs; Improved computational thinking without reporting an instrument.
S10	Putri & Agustina (2023)	Virtual experiment; projectile motion and maximum heigh	Quantitative descriptive experiment; multiple trials	Trajectories matched the parabolic model; Hmax approximated theoretical predictions with small relative errors
S11	Sariyah et al. (2022)	JHS, motion topic; hamster motion on a wheel	Direct experiment using Tracker and JavaScript programming	Motion identified as uniform rectilinear motion; Tracker-derived velocities were more precise than manual calculations
S12	Purnama et al. (2026)	Rectilinear, projectile, and circular motion.	Descriptive; development of video-based simulations	The approach was claimed to support problem solving and learning independence.

Note. Studies using video analysis applications other than Tracker (Becker et al., 2020a, 2020b) and studies outside the review period (Beichner, 1996; Wee et al., 2012) were used as contextual evidence. A study on rotational dynamics (Romadhon et al., 2024) was excluded because its topic lies outside kinematics.

The most frequently reported outcomes were science process skills, investigative skills, graph interpretation, and critical and creative thinking. S1 reported an N-gain of 0.53 in science process skills (Fitriyanto & Sucahyo, 2016), and S3 reported an N-gain of 0.68 in graph interpretation (Raflesiana et al., 2019). S2 found a positive effect on the investigative skills of junior high school students compared with instruction using PowerPoint and video (Artiningsih & Nurohman, 2019). The direction of these findings is consistent. However, these skills differ from the conceptual understanding of kinematics that is the focus of RQ1.

Only S4 explicitly examined conceptual understanding of motion, using a multiple-choice test combined with the Certainty of Response Index (CRI) and interviews. This study reported initially low understanding that improved after video-based learning with Tracker (Amaliah et al., 2020). S6 concluded that Tracker-based laboratory work improved understanding and process skills (Renika et al., 2024), but its instruments and sample require confirmation. No study in the corpus used a standardized instrument such as the TUG-K (Beichner, 1994). Accordingly, the claim that Tracker "consistently" reduces misconceptions is not yet supported by evidence from 2016–2026. This claim is better regarded as a hypothesis supported by earlier studies (Hockicko et al., 2014; Wee et al., 2012).

S3 and S5 combined Tracker with guided inquiry, whereas S7 combined it with STEM learning. The magnitude of reported change varied considerably. In S5, the N-gain in creative thinking was only 0.20, although the pre–post difference was significant (Alfayani et al., 2024). In S7, the effect size for critical thinking reached 1.82, but the experimental and control groups came from different grade levels (Zaina et al., 2026). This variation suggests that effects depend on task design, the outcome measured, and the quality of the comparison, rather than on the software alone. This interpretation is consistent with meta-analytic evidence that guidance is a key factor in the success of inquiry learning (Lazonder & Harmsen, 2016).

Table 6. Evidence-strength matrix for the main claims

Claim examined	Evidence	Strength of evidence	Critical remarks
Tracker improves conceptual understanding of kinematics	S4 (descriptive); S6 (authors' claim)	Low	No comparison group and no standardized instrument
Tracker reduces misconceptions	S4 (CRI) only	Very low	Supported by earlier studies outside the review period (Hockicko et al., 2014; Wee et al., 2012)
Tracker improves process skills, investigative skills	S1, S2, S3	Low to moderate	Consistently positive direction; only S2 had a control group
Tracker improves critical/creative thinking	S5, S7	Low	Low N-gain (S5); non-equivalent groups (S7)
Tracker measures kinematic parameters accurately	S6, S8, S9, S10, S11	Moderate	Consistent, but errors were rarely analyzed systematically
Integrating video analysis with modeling yields larger effects	No comparative study	Insufficient	A hypothesis for future research
Parallax error reduced by up to 90%	Unverifiable source	Cannot be assessed	Removed from the manuscript

To address RQ2, this review developed a five-level integration framework (Table 7). Most studies were at level L1, in which students track objects and obtain tables and graphs. The measurement studies (S8–S10) reached level L2 because they fitted data with functions to derive physical parameters. S8 obtained a mean g of 9.98 m/s² from a simple pendulum (Handayani et al., 2022), S9 derived the spring constant and gravitational acceleration from graphs (Handayani et al., 2023), and S10 showed that projectile trajectories and maximum heights agreed with the theoretical model with small relative errors (Putri & Agustina, 2023). Based on the abstracts, no study explicitly reported using Tracker's dynamic

model (L3) compared directly with the video, as described by Brown and Cox (2009) and applied by Wee et al. (2012).

The measurement studies showed good agreement between measured and theoretical values. S6 also detected the effect of air resistance on acceleration (Renika et al., 2024), and S11 reported that Tracker-derived velocities were more precise than manual calculations (Sariyah et al., 2022). However, error sources specific to video analysis, such as resolution and frame rate, parallax due to camera position, and scale calibration, were rarely quantified. The claim of a parallax error reduction "of up to 90%" originated from an unverifiable source and was therefore removed.

S9 claimed improvements in computational thinking (Handayani et al., 2023), and S11 combined Tracker with JavaScript programming (Sariyah et al., 2022). Neither study reported an instrument measuring computational practices as defined in the taxonomy of computational thinking for science classrooms, which comprises data practices, modeling and simulation practices, computational problem-solving practices, and systems thinking practices (Weintrop et al., 2016). Experience at the university level shows that computational modeling can be assessed in a structured manner: in the study by Caballero et al., 60.4% of 1,357 students successfully completed a computational modeling evaluation using VPython (Caballero et al., 2012).

Table 7. Framework of levels of integration between video analysis and modeling

Level	Form of integration	Description	Position of the corpus
L0	Visualization	Video or trajectories are displayed for observation without data extraction by students	Supporting element in S4 and S12
L1	Data extraction	Students track objects, set the scale and coordinate system, and obtain tables & graphs	Most studies (S1–S3, S5–S11)
L2	Analytical model fitting	Data are fitted with functions (e.g., parabolic, sinusoidal) to derive physical parameters	S8–S10 (based on abstracts)
L3	Tracker dynamic model	A particle model built from the laws of motion is overlaid on the video and compared with the actual motion (Brown & Cox, 2009; Wee et al., 2012)	Not explicitly reported
L4	Student-built computational model	Students write or modify programs to model motion (Caballero et al., 2012)	Partially in S11 (JavaScript)

The main finding of this review is a gap between the theoretical potential of Tracker and the empirical evidence from 2016–2026. Theoretically, Tracker provides conditions considered important for conceptual change: predictions can be confronted with real data, thereby triggering dissatisfaction with existing conceptions (Posner et al., 1982), and multiple representations of motion can be displayed simultaneously (Ainsworth, 2006). Nevertheless, the studies in the corpus mostly measured general skills using one-group designs. The conclusions that can be justified are therefore narrower than commonly claimed. Tracker is associated with improvements in process skills, investigative skills, and graph interpretation in small-scale studies, and it produces accurate kinematic data. In contrast, its effects on misconceptions and the added value of modeling have not been adequately tested.

The positive findings in the corpus align with the direction of international evidence but differ in design strength. Beichner (1996) reported a dose–response pattern: the more deeply video analysis was integrated into the curriculum, the greater the improvement in graph interpretation, whereas teacher demonstrations alone produced no improvement. This pattern helps explain why studies that actively involved students in laboratory work (S1–S3) reported improvements. The cluster-randomized trial by Becker et al. (2020a) identified a more specific mechanism, namely a reduction in extraneous cognitive load that mediated gains in conceptual understanding. This mechanism is consistent with cognitive load theory, which emphasizes the limited capacity of working memory in processing new information (Sweller et al., 2019). Automatic graph generation may free working memory capacity from manual

calculation, allowing students to focus on the meaning of representations. However, no study in the corpus measured cognitive load. This mechanism therefore remains a plausible explanation rather than a finding of this review.

At least two explanations may account for the rarity of reported use of the dynamic modeling feature. *First*, the use of Tracker in schools has been driven largely by the need for low-cost and remote laboratory work (Nisa et al., 2024), so the data extraction function has been prioritized. *Second*, dynamic modeling requires an understanding of the relationships among force, acceleration, and initial conditions, which calls for gradual scaffolding. Modeling theory views the cycle of building, testing, and revising models as the core of physics learning (Hestenes, 1987). Without level L3, students may measure motion without necessarily modeling it. Consequently, the claim that integrating video analysis and modeling produces larger effects needs to be tested directly, for example by comparing L1–L2 classes with L3 classes on the same content.

Based on this synthesis, Table 8 proposes a laboratory design that follows the phases of inquiry (Pedaste et al., 2015) and progressively raises the level of video–model integration. The element least frequently found in the corpus, namely written predictions before the experiment, is deliberately placed at the beginning so that cognitive conflict becomes observable. The design also treats the planning of video recording as part of experimental design rather than as mere technical preparation, in line with the argument that laboratory work should involve students in scientific decision-making (Hofstein & Lunetta, 2004).

Table 8. Proposed Tracker-based kinematics laboratory design

Inquiry phase	Tracker-based activities	Theoretical basis	Evidence/indicators
Orientation and conceptualization	Written predictions and sketches of x–t/v–t graphs before the experiment	Cognitive conflict (Posner et al., 1982); graph difficulties	Prediction sheets; diagnostic items
Investigation: design	Planning the recording: camera perpendicular to the plane of motion, reference scale, frame rate, lighting	Hofstein & Lunetta (2004)	Experimental design rubric
Investigation: data and model	Automatic/manual tracking (L1), function fitting (L2), then a dynamic model (L3) compared with the video	Modeling (Hestenes, 1987); multiple representations	Model–data agreement; residuals
Conclusion	Comparing predictions, data, and models; explaining discrepancies and sources of error	Cognitive conflict; Beichner (1996)	Posttest with standardized instruments
Discussion and reflection	Group presentations and written reflections on measurement limitations	Social scaffolding; inquiry guidance	Reflection journals; observation

Theoretically, the five-level integration framework provides more precise language for distinguishing “using Tracker” from “modeling with Tracker”. This distinction can be used as a moderator variable in future studies. Practically, teachers can use Tracker with simple equipment, such as mobile phone cameras, provided that recordings are planned with attention to camera position, reference scale, and frame rate. Tasks should also be structured so that students predict, measure, model, and explain discrepancies between models and data. The dose–response pattern reported by Beichner (1996) suggests that occasional use as a demonstration is unlikely to be sufficient. This review has several limitations. Data extraction for some studies was based on abstracts; therefore, details of the instruments, samples, and Tracker features used require confirmation from the full texts. The corpus is dominated by small-scale Indonesian studies, which limits the transferability of the findings to other contexts. Finally, restricting the review to Tracker excluded studies using other video analysis applications with stronger designs, although these studies were drawn upon as contextual evidence

IV. CONCLUSION

This systematic review yields three conclusions. First, regarding RQ1, Tracker-based learning, usually combined with guided inquiry or STEM, is consistently reported to improve science process skills, investigative skills, graph interpretation, and critical and creative thinking. However, most of these improvements derive from one-group or non-equivalent group designs. Evidence on conceptual understanding and the remediation of kinematics misconceptions in 2016–2026 remains very limited and has not relied on standardized instruments. Second, regarding RQ2, the integration of video analysis and modeling in the corpus largely remains at the levels of data extraction and function fitting. At these levels, Tracker has been shown to produce kinematic parameters consistent with theoretical values, whereas the use of dynamic models compared directly with video has not been explicitly reported. Third, the potential of Tracker as a tool for conceptual change and modeling is supported by theory and earlier international studies but still needs to be tested through studies with equivalent comparison groups, standardized conceptual instruments, measures of cognitive load, and direct comparisons between integration levels.

V. REFFERENCE

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16*(3), 183–198. https://doi.org/10.1016/j.learninstruc.2006.03.001

Alfayani, C., Suana, W., & Viyanti, V. (2024). Pengaruh pembelajaran blended learning menggunakan Tracker pada materi gerak harmonis sederhana berbasis inkuiri terbimbing terhadap peningkatan kemampuan berpikir kreatif siswa [Effect of blended learning using Tracker on guided-inquiry-based simple harmonic motion on students' creative thinking skills]. *JIPFRI (Jurnal Inovasi Pendidikan Fisika dan Riset Ilmiah), 8*(1), 29–38. https://doi.org/10.30599/jipfri.v8i1.3315

Amaliah, N. U., Darmadi, I. W., & Saehana, S. (2020). Analysis of students' understanding of motion concept with video based learning assisted by Tracker software. *Berkala Ilmiah Pendidikan Fisika, 8*(2), 126–132. https://doi.org/10.20527/bipf.v8i2.8369

Artiningsih, A., & Nurohman, S. (2019). Analysis of investigative skills based on the use of tracker video analysis for 21th century skill. *Journal of Science Education Research, 3*(2), 81–86. https://doi.org/10.21831/jser.v3i2.30621

Becker, S., Klein, P., Gößling, A., & Kuhn, J. (2020a). Using mobile devices to enhance inquiry-based learning processes. *Learning and Instruction, 69*, Article 101350. https://doi.org/10.1016/j.learninstruc.2020.101350

Becker, S., Klein, P., Gößling, A., & Kuhn, J. (2020b). Investigating dynamic visualizations of multiple representations using mobile video analysis in physics lessons: Effects on emotion, cognitive load and conceptual understanding. *Zeitschrift für Didaktik der Naturwissenschaften, 26*(1), 123–142. https://doi.org/10.1007/s40573-020-00116-9

Beichner, R. J. (1994). Testing student interpretation of kinematics graphs. *American Journal of Physics, 62*(8), 750–762. https://doi.org/10.1119/1.17449

Beichner, R. J. (1996). The impact of video motion analysis on kinematics graph interpretation skills. *American Journal of Physics, 64*(10), 1272–1277. https://doi.org/10.1119/1.18390

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health, 11*(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Brown, D., & Cox, A. J. (2009). Innovative uses of video analysis. *The Physics Teacher, 47*(3), 145–150. https://pubs.aip.org/aapt/pte/article-abstract/47/3/145/275154/Innovative-Uses-of-Video-Analysis

Caballero, M. D., Kohlmyer, M. A., & Schatz, M. F. (2012). Implementing and assessing computational modeling in introductory mechanics. *Physical Review Special Topics—Physics Education Research, 8*(2), Article 020106. https://doi.org/10.1103/PhysRevSTPER.8.020106

Fitriyanto, I., & Sucahyo, I. (2016). Penerapan software Tracker video analyzer pada praktikum kinematika gerak [Application of Tracker video analyzer software in kinematics laboratory work]. *Inovasi Pendidikan Fisika, 5*(3). https://ejournal.unesa.ac.id/index.php/inovasi-pendidikan-fisika/article/view/19949

Gusenbauer, M., & Haddaway, N. R. (2020). Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. *Research Synthesis Methods, 11*(2), 181–217. https://doi.org/10.1002/jrsm.1378

Habibbulloh, M., & Madlazim, M. (2014). Penerapan metode analisis video software Tracker dalam pembelajaran fisika konsep gerak jatuh bebas untuk meningkatkan keterampilan proses siswa kelas X SMAN 1 Sooko Mojokerto [Application of the Tracker video analysis method in physics learning of the free-fall concept to improve the process skills of grade X students at SMAN 1 Sooko Mojokerto]. *Jurnal Penelitian Fisika dan Aplikasinya (JPFA), 4*(1), 15–22. https://doi.org/10.26740/jpfa.v4n1.p15-22

Handayani, I. D., Ahmad, F., & Aryati P. L., D. (2022). Efektivitas Tracker video analysis dalam praktikum fisika untuk menentukan percepatan gravitasi [Effectiveness of Tracker video analysis in physics laboratory work for determining gravitational acceleration]. *ORBITA: Jurnal Pendidikan dan Ilmu Fisika, 8*(2), 328–332. https://doi.org/10.31764/orbita.v8i2.10766

Handayani, I. D., Lestari, D. A. P., & Sulistyowati, S. (2023). Analisis konstanta pegas dan percepatan gravitasi ayunan sederhana dengan Tracker video analysis untuk meningkatkan computational thinking [Analysis of the spring constant and gravitational acceleration of a simple pendulum using Tracker video analysis to improve computational thinking]. *ORBITA: Jurnal Pendidikan dan Ilmu Fisika, 9*(1), 155–161. https://doi.org/10.31764/orbita.v9i1.13671

Hestenes, D. (1987). Toward a modeling theory of physics instruction. *American Journal of Physics, 55*(5), 440–454. https://doi.org/10.1119/1.15129

Hockicko, P., Trpišová, B., & Ondruš, J. (2014). Correcting students' misconceptions about automobile braking distances and video analysis using interactive program Tracker. *Journal of Science Education and Technology, 23*(6), 763–776. https://doi.org/10.1007/s10956-014-9510-z

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28–54. https://doi.org/10.1002/sce.10106

Hong, Q. N., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Gagnon, M.-P., Griffiths, F., Nicolau, B., O'Cathain, A., Rousseau, M.-C., Vedel, I., & Pluye, P. (2018). The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. *Education for Information, 34*(4), 285–291. https://doi.org/10.3233/EFI-180221

Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research, 86*(3), 681–718. https://doi.org/10.3102/0034654315627366

McDermott, L. C., Rosenquist, M. L., & van Zee, E. H. (1987). Student difficulties in connecting graphs and physics: Examples from kinematics. *American Journal of Physics, 55*(6), 503–513. https://doi.org/10.1119/1.15104

Nisa, M. K., Kurniawan, W., & Nuroso, H. (2024). Tren penggunaan software Tracker dalam fisika: Systematic-review [Trends in the use of Tracker software in physics: A systematic review]. *Lontar Physics Today, 3*(3), 120–129. https://doi.org/10.26877/lpt.v3i3.21878

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, Article n71. https://doi.org/10.1136/bmj.n71

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211–227. https://doi.org/10.1002/sce.3730660207

Purnama, A. Y., Istiyono, E., Ariswan, A., & Nurhanafi, K. (2026). Simulation of the use of analysis video tracker software in kinematics material as an alternative distance learning. *Revista Mexicana de Física E, 23*(2), Article 020204. https://doi.org/10.31349/RevMexFisE.23.020204

Putri, A. S., & Agustina, R. R. (2023). Enhancing physics learning through virtual experiments: Analyzing parabolic motion and maximum height using Tracker software. *ISEJ: Indonesian Science Education Journal, 4*(3), 86–94. https://doi.org/10.62159/isej.v4i3.1756

Raflesiana, V., Herlina, K., & Wahyudi, I. (2019). Pengaruh penggunaan Tracker pada pembelajaran gerak harmonik sederhana berbasis inkuiri terbimbing terhadap keterampilan interpretasi grafik siswa [Effect of using Tracker in guided-inquiry learning of simple harmonic motion on students' graph interpretation skills]. *Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika, 5*(1). https://doi.org/10.30870/gravity.v5i1.5207

Rahmadani, U., Sundari, P. D., Hidayati, H., & Dewi, W. S. (2023). Systematic review of misconceptions in kinematics: Identification, causes, and remediation. *Jurnal Penelitian Pendidikan IPA, 9*(12), 1274–1283. https://doi.org/10.29303/jppipa.v9i12.4956

Renika, J., Prima, E. C., & Amprasto, A. (2024). Kinematics analysis on accelerated motion using tracker video analysis for educational purposes. *Momentum: Physics Education Journal, 8*(1), 23–31. https://doi.org/10.21067/mpej.v8i1.8883

Romadhon, D. R., Muslim, M. A. B., & Suwarna, I. P. (2024). Video-based laboratories in physics: A quasi-experimental study on rotational dynamics and critical thinking enhancement. *Jurnal Pijar MIPA, 19*(4), 732–737. https://doi.org/10.29303/jpm.v19i4.7266

Sariyah, Kuswanto, H., Nurcahyo, H., Ilma, A. Z., & Hujatulatif, A. (2022). Hamster (Cricetinae) motion assisted by video tracker application on motion materials in junior high school. *Jurnal Penelitian Pendidikan IPA, 8*(6). https://doi.org/10.29303/jppipa.v8i6.1583

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review, 31*(2), 261–292. https://doi.org/10.1007/s10648-019-09465-5

Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology, 8*, Article 45. https://doi.org/10.1186/1471-2288-8-45

Thornton, R. K., & Sokoloff, D. R. (1990). Learning motion concepts using real-time microcomputer-based laboratory tools. *American Journal of Physics, 58*(9), 858–867. https://doi.org/10.1119/1.16350

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press. https://www.hup.harvard.edu/books/9780674576292

Wee, L. K., Chew, C., Goh, G. H., Tan, S., & Lee, T. L. (2012). Using Tracker as a pedagogical tool for understanding projectile motion. *Physics Education, 47*(4), 448–455. https://doi.org/10.1088/0031-9120/47/4/448

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology, 25*(1), 127–147. https://doi.org/10.1007/s10956-015-9581-5

Zaina, A., Al Farizi, Z., & Nurfadilah. (2026). The effectiveness of video tracker use in STEM-based linear motion learning to improve students' critical thinking skills. *Jurnal Penelitian Pembelajaran Fisika, 17*(1), 55–63. https://doi.org/10.26877/jp2f.v17i1.2323