Epistemological Beliefs and Computational Modeling in Physics Education: A Critical Integrative Review

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ABSTRACT

Computational modeling has become an important approach in physics education because it enables learners to represent physical systems, test assumptions, and interpret simulated phenomena. Learning through computational models also requires learners to consider how scientific knowledge is constructed, evaluated, and justified, which connects modeling with epistemological beliefs and epistemic cognition. This critical integrative review examines how epistemological beliefs and related epistemic processes are addressed in research on computational modeling in university physics education published between 2010 and 2026. A preliminary web-based search identified 14 records. Two conference abstracts without accompanying papers were set aside, and 12 records were screened at the abstract level by a single reviewer against explicit eligibility criteria. Seven records were retained: three peer-reviewed core studies, two peer-reviewed related studies that address epistemology-adjacent constructs, and two preprints treated as emerging evidence. The evidence is small, qualitative, and concentrated in intermediate and upper-division courses. Epistemic framing, practice-based, and computational-literacy perspectives predominate, and no retained study tracked change with a stable-beliefs survey such as the Colorado Learning Attitudes about Science Survey (CLASS) or the Maryland Physics Expectations Survey (MPEX). One interview study reports a before-and-after shift in epistemic framing, and one study offers an explicit metamodel of computational modeling; the remaining records describe categories of practice and belief rather than change. Recurring design features include troubleshooting simulations against physics principles, open-ended computational artifacts, making, and scaffolding that shapes how students frame code. Because database searches, independent screening, full-text assessment, and formal quality appraisal have not been completed, the findings are provisional and no causal claims are made. The review offers instructional implications, a research agenda, and a specification of the procedures required for a full systematic review.

Keywords: computational modeling; physics education; epistemological beliefs; epistemic cognition; computational experiments; scientific reasoning

INTRODUCTION

Background

Computation is widely regarded as a third pillar of physics alongside theory and experiment, and programming environments such as VPython, Python, and Jupyter notebooks have entered introductory and advanced physics courses (Chabay & Sherwood, 2008; Caballero et al., 2012). Learning goals for such courses usually include both computational skills and a more sophisticated understanding of how physics knowledge is built.

Epistemological Beliefs in Physics Learning

Students' beliefs about the nature of knowing shape how they study, what they count as understanding, and whether they persist. Personal epistemology research describes development across dimensions such as certainty, source, and justification of knowledge (Perry, 1970; Schommer, 1990; Hofer & Pintrich, 1997). Physics education research developed discipline-specific surveys, including the MPEX (Redish et al., 1998) and CLASS (Adams et al., 2006), which typically show that conventional instruction leaves students' views unchanged or less expert-like. Hammer (1994) described students' beliefs about coherence, formulas, and learning in physics,

and later work reframed epistemologies as context-sensitive resources activated by framing rather than as stable beliefs (Hammer & Elby, 2002; Hammer et al., 2005). Research on practical epistemologies in inquiry settings similarly locates epistemic stances in what students do while investigating (Sandoval, 2005).

Computational Modeling as an Epistemic Practice

Writing code to represent a physical system is a form of model construction: the program is an explicit, runnable commitment about how a system behaves, and it can be tested, debugged, compared with data, and revised. This aligns with model-based views of science (Giere, 1999; Hestenes, 1992) and with philosophical analyses of how simulations generate knowledge (Humphreys, 2004; Winsberg, 2010). Science education research on metamodeling knowledge holds that students' views of what models are and what they are for affect how they reason with them (Grosslight et al., 1991; Schwarz & White, 2005). Coding may therefore influence epistemological beliefs about coherence, approximation, the role of mathematics, the role of experiment, and the status of models.

Rationale and Gap

Studies of computational physics instruction often report skill or conceptual outcomes, whereas epistemological outcomes are measured less often, with different constructs and instruments, and under competing assumptions. In the preliminary search reported here, we did not identify a review that synthesizes epistemological outcomes specifically in computational modeling contexts in physics. Because the relevant literature appears small, methodologically diverse, and spread across empirical studies and theoretical frameworks, an integrative design, which can combine such sources into a critical account of an emerging topic, is appropriate (Torraco, 2005; Whittemore & Knafl, 2005).

Aim and Research Questions

The aim of this review is to synthesize, in a preliminary and critical manner, the available evidence on how computational modeling relates to epistemological beliefs, epistemic resources, and views of models in university physics education. Five research questions guided the review.

RQ1. What study characteristics (educational level, tool, physics topic, design) define research linking computational modeling and epistemology in physics?

RQ2. How are epistemological beliefs conceptualized (stable beliefs, contextual resources, practices) and measured?

RQ3. What changes in epistemological beliefs or resources are reported in relation to computational modeling instruction?

RQ4. Which instructional features (model-testing cycles, debugging, data comparison, reflection prompts, scaffolding) are described in this research?

RQ5. How are views about the nature and purpose of scientific models addressed?

METHODS

Design and Reporting

This study is a critical integrative review. It is not a systematic review. The review followed the five stages described by Whittemore and Knafl (2005): problem identification, literature search, data evaluation, data analysis, and presentation. Elements of the PRISMA 2020 statement (Page et al., 2021) were used as a transparency guide only for the stages that were completed, namely the reporting of identification and screening counts and of reasons for exclusion. Compliance with the full PRISMA checklist is not claimed. Meta-analysis was not attempted because the retained records are qualitative or exploratory and use non-comparable constructs. Table 1 lists each review procedure and whether it has been completed.

Table 1. Status of Review Procedures

Procedure	Status	Note
Preliminary open-web search	Completed	Seven web searches and one full-text retrieval on 22 October 2026.
Deduplication	Completed	Manual, across the 14 records identified.
Abstract-level screening	Completed (single reviewer)	No second reviewer; inter-rater agreement (kappa) is not available.
Multi-database search (Scopus, Web of Science, ERIC, APA PsycInfo, Physical Review Physics Education Research archive)	Not completed	Planned for the extended review.
Hand-searching and citation chasing	Not completed	Planned for the extended review.
Independent dual screening of titles, abstracts, and full texts	Not completed	Planned for the extended review.
Full-text assessment of all retained records	Not completed	One full text was retrieved during the search; other records were assessed from abstracts and repository summaries.
Data extraction	Partial	Abstract-level fields only (Table 3 and Table 4).
Formal methodological appraisal (MMAT; Hong et al., 2018)	Not completed	Descriptive notes on design limits are given instead.
Peer review of search strategy (PRESS; McGowan et al., 2016)	Not completed	Planned for the extended review.
Protocol registration	Not performed	To be registered before the extended review begins.
PRISMA 2020 flow diagram	Replaced	A simplified flow of record counts is given in Figure 1.

Note. MMAT = Mixed Methods Appraisal Tool; PRESS = Peer Review of Electronic Search Strategies.

Eligibility Criteria

The criteria in Table 2 were applied in the same way to all 12 records assessed. An epistemology-related outcome was defined as beliefs, resources, framing, practices, or views of models. Records with only affective or attitudinal outcomes, such as anxiety, self-efficacy, mindset, or attitudes toward programming, were treated as outside this criterion. Retained records were classified as follows. Core records are peer-reviewed and show an epistemology-related outcome in the abstract. Related records are peer-reviewed and university-level but address epistemology-adjacent constructs, such as students' views of computation as a physics practice, so that the epistemological outcome is indirect. Preprints otherwise fit the criteria but were not peer reviewed at the time of the search and are treated as emerging evidence rather than as part of the evidence base.

Table 2. Eligibility Criteria

Element	Inclusion	Exclusion
Population	University physics learners (undergraduate primary) or physics teachers	Samples without physics-specific data; secondary-school samples (recorded, not synthesized)
Phenomenon	Student-written or student-modified code used to build, test, or analyze a physics model	Passive simulation use only (e.g., PhET alone); computer science education without physics content
Outcome	At least one epistemology-related outcome, measured or qualitatively analyzed (beliefs, resources, framing, practices, or views of models)	No epistemology-related outcome; affective or attitudinal outcomes only

Design	Empirical qualitative, quantitative, or mixed-methods studies	Opinion pieces, editorials, unreviewed abstracts, posters without a full paper
Source	Peer-reviewed journals and full conference proceedings, 2010–2026; preprints recorded separately	Theses, non-peer-reviewed reports
Language	English	Other languages without reliable translation

Note. Both belief-based and resource-based approaches are eligible, as are qualitative studies (interviews, video analysis, reflective writing, analysis of student work).

Information Sources and Search

A preliminary search was run on 22 October 2026 with an AI-assisted web search tool (Claude, Anthropic), comprising seven web searches and one full-text retrieval. The query terms combined computational modeling and programming in physics education with epistemology-related terms (beliefs, framing, resources, practices, and attitudes). The sources reached were open-access and openly indexed pages, including journal and publisher pages, the Directory of Open Access Journals, the PER-Central and ComPADRE repositories, conference archives, and arXiv. The databases named in Table 1 were not searched, and hand-searching and citation chasing were not done. The search is therefore exploratory and not exhaustive, and it is likely to favor open-access and arXiv sources.

Selection Process

Records were deduplicated manually. A single reviewer screened the records from abstracts and repository summaries, supported by the AI tool described above, and one full text was retrieved. No second reviewer was involved, so no inter-rater agreement is reported. In preparing this revision, the bibliographic details and publication venue of every record were rechecked against publisher, repository, or conference-archive records, and the eligibility criteria were reapplied uniformly. This reapplication changed the classification of two records (Kohlmyer et al., 2011; Lunk & Beichner, 2016), which had been held as pending and are now excluded because they report attitudinal outcomes only. Full-text assessment of the retained records is still pending.

Data Extraction

Data were extracted at the abstract level into a form capturing educational context and sample, design, tool or task, epistemic focus, instrument or method, and the direction of change as reported by the study authors. Fields that need full texts, namely the alignment between intervention design and the epistemological outcome, dimension targeted, and detailed instructional features, were not extracted and are planned for the extended review.

Methodological Appraisal

Formal appraisal with the MMAT was not performed because it requires full texts. Design features and their inherent limits are described in the Results instead, and no causal claims are drawn from the retained records.

Synthesis

RQ1 was addressed by descriptive mapping. RQ2 to RQ5 were addressed by narrative synthesis organized by research question, using two a priori strands as an organizing lens: Strand A (personal and physics epistemology) and Strand B (philosophy of models and simulation). A cross-tabulation of instructional features against direction of change was not attempted, because with seven retained records it would be anecdotal. Findings are reported separately for core, related, and preprint records so that the strength of each claim stays visible.

Reflexivity and Ethics

Interpretation reflects the authors' disciplinary positions in physics education and educational psychology. Every classification decision is recorded in Table 3 to provide an audit trail. Ethical approval was not required because only published data were used.

RESULTS

Study Selection

The preliminary search identified 14 distinct records (Figure 1). Two were conference abstracts with no accompanying paper and were set aside. Of the 12 records assessed, five were excluded: two reported no epistemology-related outcome (Caballero et al., 2012; Odden & Caballero, 2019), one was set in secondary school and focused on affective constructs (Hamerski et al., 2022), and two reported attitudes only (Kohlmyer et al., 2011; Lunk & Beichner, 2016). Seven records were retained: three core studies, two related studies, and two preprints.

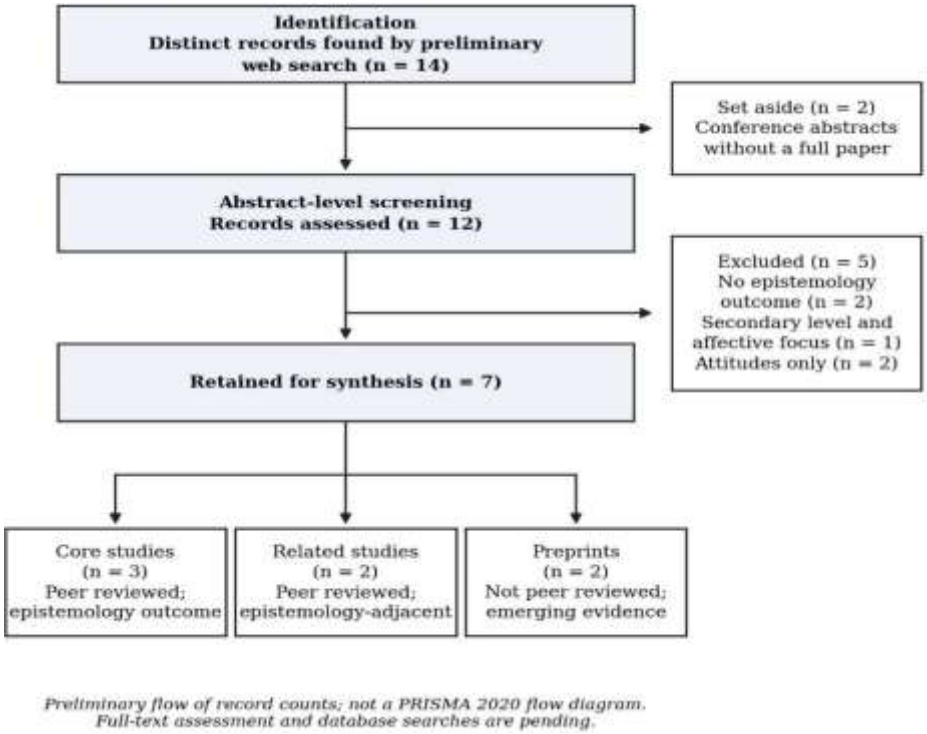

Figure 1. Preliminary flow of records from identification to synthesis.

Characteristics of the Records (RQ1)

Table 3 gives the characteristics and classification of all 12 records assessed. The seven retained records were published between 2012 and 2026 and are all university-level. Contexts are intermediate and upper-division courses (a third-semester electricity and magnetism course, an intermediate physics course, upper-division computationally integrated courses, a computational physics lab, and a modern physics lab) and one computational physics class incorporating making. No retained record addressed secondary-school learners or teachers. The designs are qualitative or exploratory: interviews (Bodin, 2012; Lane & Headley, 2022; Nearhood & Hamerski, 2025), content analysis of student work (Phillips et al., 2023), exploratory case study of computational essays (Odden et al., 2019), and case studies (McHale et al., 2026; Odden & Zwickl, 2024). The computational tasks include a particle-spring simulation, computational essays that combine executable code with narrative, and making activities that pair physical and digital artifacts.

Table 3. Characteristics and Classification of the Records Assessed

Record	Context and sample	Epistemic focus	Venue and status	Classification
Bodin (2012)	University physics students; particle-spring simulation task; interviews before and after	Epistemic framing, analyzed with epistemic networks	Peer-reviewed journal (*Physical Review Special Topics – Physics Education Research*)	Core

Odden et al. (2019)	Third-semester electricity and magnetism course; computational essays; exploratory case study	Practices, knowledge, and beliefs within a computational literacy framework	Peer-reviewed journal (*Physical Review Physics Education Research*)	Core
Phillips et al. (2023)	Computational physics class incorporating making; content analysis of student work	Epistemic metamodel drawing on philosophy of science	Peer-reviewed journal (*Physical Review Physics Education Research*)	Core
Lane & Headley (2022)	Five students after three concurrent computationally integrated upper-division courses; semi-structured interviews	Representations of computation as a practice of the physics community	Peer-reviewed journal (*Physical Review Physics Education Research*); arXiv version 2112.05581	Related
Nearhood & Hamerski (2025)	Five students in a one-credit upper-division computational physics lab; interviews at the end of the second of three terms	Experiences under the Physics Computational Literacy framework; assumptions about social computational literacy	Conference proceedings (PERC 2025); arXiv:2603.12158	Related
Odden & Zwickl (2024)	Two pairs of students writing computational essays in an intermediate physics course	Disciplinary computational literacy; essays as an epistemic form	Preprint (arXiv:2403.15028); submitted to a journal	Preprint
McHale et al. (2026)	Comparative case study of a multi-day activity in an upper-level, computationally integrated modern physics lab	Epistemic framing of code; computational literacy beliefs; physics identity	Preprint (arXiv:2601.10005)	Preprint
Caballero et al. (2012)	1,357 students; VPython homework	Modeling proficiency and common student errors	Peer-reviewed journal	Excluded: No epistemology outcome
Odden & Caballero (2019)	Pilot in introductory electricity and magnetism; computational essays	Student creativity	Conference proceedings (PERC 2019)	Excluded: No epistemology outcome
Hamerski et al. (2022)	High school AP physics case study	Computational challenges; mindset, self-concept, and self-efficacy	Peer-reviewed journal (*Physical Review Physics Education Research*)	Excluded: Secondary level; affective outcomes
Kohlmyer et al. (2011)	Introductory mechanics at Georgia Tech (N = 316 on the poster), with electricity and magnetism and North Carolina State samples; COMPASS survey	Attitudes, interests, and values about computation	Conference poster; no full paper located	Excluded: Attitudes only; poster
Lunk & Beichner (2016)	Life science majors in introductory physics; exploratory study	Attitudes toward programming and spreadsheets	Conference proceedings (PERC 2016)	Excluded: Attitudes only

Note. PER = Physics Education Research; PERC = Physics Education Research Conference; COMPASS = Computation Modeling in Physics Attitudinal Student Survey. Details were checked against publisher, repository, or conference-archive records and are at the abstract level.

Methodological Characteristics of the Evidence

Formal appraisal was not performed (Table 1). From the abstracts, all seven retained records use qualitative, small-sample designs, and where sample size is reported it is small (five students in each of two interview studies; two pairs of students in one case study). None of the retained records has a comparison group. The evidence is therefore descriptive and is best treated as theory-building. It cannot support claims that coding changes epistemologies. Two of the seven retained records are preprints whose findings may change in peer review.

Conceptualization and Measurement of Epistemology (RQ2)

Resource-, practice-, and literacy-based framings dominate the retained records (Table 4). Bodin (2012) analyzed epistemic framing by applying network analysis to interview transcripts, an approach that fits the resources view. Odden et al. (2019) treated beliefs as one component, alongside practices and knowledge, of a computational literacy framework with material, cognitive, and social aspects, and Odden and Zwickl (2024) and Nearhood and Hamerski (2025) built on this framework. Phillips et al. (2023) constructed a practice-based epistemic metamodel from the philosophy of science. Lane and Headley (2022) used a communities-of-practice lens to examine how students represent computation within the physics community, and McHale et al. (2026) linked epistemic framing of code to computational literacy beliefs and physics identity.

No retained record used a stable-beliefs survey, such as CLASS or MPEX, to track change in a modeling course. The one dedicated survey encountered, the COMPASS, is a 36-item five-point Likert instrument for attitudes, interests, and values about computation (Kohlmyer et al., 2011). It targets attitudes rather than epistemology and was reported in a poster, so it was excluded under the criteria in Table 2. This pattern reflects only what the preliminary search reached, and a targeted CLASS and MPEX search in Scopus and ERIC is needed to test it.

Table 4. Epistemic Stance, Method, and Reported Findings in the Retained Records

Record	Epistemic stance	Method	Reported finding	Evidence of change
Bodin (2012)	Resources and framing	Interviews before and after; epistemic network analysis	Students shifted from framing the task as modeling, with expectations about learning programming, to framing it as a physics task, using physics principles and conservation laws to troubleshoot.	Yes: qualitative, before-and-after evidence
Odden et al. (2019)	Practices, knowledge, and beliefs (literacy)	Exploratory case study; student essays	Categories of practices, knowledge, and beliefs were identified across material, cognitive, and social aspects. Benefits and limitations of open-ended projects were discussed.	None measured
Phillips et al. (2023)	Practice-based metamodel	Content analysis of student work	Students made complex epistemic maneuvers while modeling; the metamodel was used to interpret their practices.	None measured
Lane & Headley (2022)	Community-of-practice views	Semi-structured interviews with five students	Students viewed computation as a normal and valuable part of physics practice, struggled with confidence, and held some proficiency expectations misaligned with the community.	None (one time point)
Nearhood & Hamerski (2025)	Aspects of computational literacy	Semi-structured interviews with five students	Students described trade-offs between developing different aspects of computational literacy. Approaches to social computational literacy varied across individuals and were driven by unspoken assumptions.	None (one time point)

Odden & Zwickl (2024)	Disciplinary computational literacy	Case studies of two pairs of students	Computational essays were proposed as a useful epistemic form for developing computational literacy.	Case-based; none measured
McHale et al. (2026)	Epistemic framing; literacy beliefs; identity	Comparative case study	Scaffolding in the activity could activate different epistemic frames, linked to divergent self-perceptions.	Illustrative cases; change not measured

Note. Findings are summarized from abstracts and repository summaries. Odden & Zwickl (2024) and McHale et al. (2026) are preprints.

Reported Changes in Epistemology (RQ3)

Only one retained study reports a before-and-after shift, and it is a shift in framing rather than a score. Bodin (2012) found that students moved from framing the task around learning programming to framing it around physics principles and conservation laws while they troubleshot their simulations, which the author interprets as the development of a more coherent view of the importance of physics principles in problem solving. The other retained peer-reviewed studies describe categories of practice and belief (Odden et al., 2019; Phillips et al., 2023) or students' views at a single time point (Lane & Headley, 2022; Nearhood & Hamerski, 2025). Among the preprints, McHale et al. (2026) report that scaffolding activated different epistemic frames that were linked to divergent self-perceptions; this is a case-based illustration of how framing relates to affect, not evidence of average change. Taken together, the evidence shows that epistemic frames and practices can be observed in computational modeling settings but does not show that modeling improves epistemological sophistication.

Instructional Features (RQ4)

Four design features recur in the retained records. Because the evidence cannot support a features-by-direction cross-tabulation, they are reported as a pattern list.

1. Troubleshooting a simulation against physics principles (Bodin, 2012).

2. Open-ended computational artifacts, such as computational essays (Odden et al., 2019; Odden & Zwickl, 2024).

3. Making shared physical and digital artifacts (Phillips et al., 2023).

4. Provided scaffolding, such as a supplied function, that shapes how students frame code (McHale et al., 2026).

The abstracts reviewed do not identify explicit reflection prompts as a designed or compared feature, so the role of reflection could not be assessed at this stage.

Views of Scientific Models (RQ5)

Among the retained records, only Phillips et al. (2023) treat views of scientific models as a central concern. Their metamodel uses the philosophy of science to describe computational modeling as a set of interacting practices, and they apply it to student work, adopting a pragmatic stance on what counts as a model, theory, and knowledge. The excluded study by Caballero et al. (2012) addresses modeling proficiency and common student errors rather than views of models, so the construct of computational modeling is available in the literature but was not treated there as an epistemological outcome. No retained record applied metamodeling knowledge (Schwarz & White, 2005) or Grosslight-style interviews (Grosslight et al., 1991) to coding, although this finding is limited by the scope of the search.

DISCUSSION

Summary of Findings

This preliminary integrative review set out to establish what is known about how epistemological beliefs and related processes are addressed in computational modeling in university physics education. Seven records were retained from a non-exhaustive search. They share three features. They are qualitative and small in scale; they treat epistemology mainly as framing, practice, or literacy rather than as stable beliefs; and they describe what students do and say more often than they measure change. One interview study documents a shift in epistemic framing, and one study provides an explicit metamodel of computational modeling. The evidence base is too limited to say whether computational modeling is associated with more sophisticated epistemologies.

Interpretation

The clearest pattern concerns the conditions under which epistemic shifts were observed. In Bodin's (2012) study, the shift in framing occurred in a task where students had to reconcile a running simulation with physics principles and conservation laws. This suggests that the epistemic value of coding may lie less in programming itself than in the moments when a model's behavior is tested against what physics says should happen. That interpretation is consistent with the view of code as an executable commitment that can be tested and revised, but it rests on a single study and should be treated as a hypothesis. The same caution applies to reflection. Reflection is often proposed as the mechanism that converts modeling experience into epistemological learning, yet none of the retained abstracts presents it as a designed or compared feature, so its contribution remains untested in this literature.

A second pattern concerns measurement. The retained studies relied on interviews, analysis of student work, and case studies, which fit a resources-and-framing view of epistemology (Hammer & Elby, 2002; Hammer et al., 2005). Surveys such as CLASS and MPEX were designed to capture general beliefs about physics and learning. They may therefore be insensitive to shifts that coding tasks plausibly produce, such as changes in how students regard code, approximation, or the status of a simulation. No retained study compared instruments, so this tension is a matter for empirical testing and not a finding. Pairing surveys with discourse or artifact analysis would allow both possibilities to be examined.

A third pattern concerns how fully the epistemic character of code is used. Phillips et al. (2023) place the testing and revision of models at the center of their metamodel, and Bodin's task works through troubleshooting. In several other retained records, code appears mainly as a medium for building computational literacy or for writing computational essays. From abstracts alone, it is not possible to determine whether code's role as an executable and falsifiable model is exploited in instruction or whether coding functions mostly as a calculation tool; full-text assessment is needed to answer this question. Finally, the related and preprint records suggest that epistemic framing is entangled with affect and identity: students' confidence, their assumptions about collaboration, and the scaffolding they receive appear alongside the epistemic frames they adopt (Lane & Headley, 2022; McHale et al., 2026; Nearhood & Hamerski, 2025). Epistemological outcomes in computational settings may therefore be difficult to separate from how students position themselves in the physics community.

Comparison with Prior Literature

The retained records fit the resources-based reframing of epistemology in physics (Hammer & Elby, 2002; Hammer et al., 2005), in which epistemic stances are activated by context and framing. They also resonate with research on practical epistemologies, which locates epistemic stances in students' actions during inquiry (Sandoval, 2005). By contrast, the large body of survey-based work showing that conventional instruction leaves views unchanged or less expert-like (Adams et al., 2006; Redish et al., 1998) has no counterpart in the retained records, which means that it remains unknown whether modeling-based courses shift scores on these instruments. On models, the metamodel of Phillips et al. (2023) draws on philosophical analyses of computational modeling and extends the science education tradition of metamodeling knowledge (Grosslight et al., 1991; Schwarz & White, 2005) into computational physics, but the retained records did not report students' views of simulations as sources of knowledge (Humphreys, 2004; Winsberg, 2010). The attitude research set aside in this review, such as the COMPASS (Kohlmyer et al., 2011) and the study of life science majors (Lunk

& Beichner, 2016), shows that affective responses to computation have received more attention than epistemological ones, which supports the gap identified in the Introduction.

Implications

The implications below follow from a small and provisional evidence base and are offered as design hypotheses and priorities.

Research. Studies should state their epistemological theory explicitly and say whether they treat epistemology as stable beliefs, contextual resources, or practices. Instruments sensitive to modeling practices are needed, together with mixed-methods designs that pair surveys with discourse or artifact analysis and, where feasible, comparison groups.

Practice. Instructors may design modeling tasks so that students must test and troubleshoot a simulation against physics principles, as in the task studied by Bodin (2012), and make the limitations of models explicit. Because reflection has not been tested in this literature, instructors who add it should treat it as an experiment worth documenting.

Curriculum. Coding tasks across the physics sequence can be aligned with intended epistemological learning goals, with attention to how scaffolding and group norms shape the way students frame code.

STRENGTHS AND LIMITATIONS

The review is explicit about its provisional status, applies one set of eligibility criteria to all records, separates peer-reviewed from preprint evidence, and checked each record's bibliographic details and venue against publisher, repository, or conference-archive records. Its limitations are substantial. The search was limited to open-web sources and did not include the major databases, hand-searching, or citation chasing, so relevant studies, especially those behind paywalls, may have been missed. Screening was done at the abstract level by a single reviewer using an AI-assisted tool, with no independent second reviewer, no full-text assessment of most records, and no formal quality appraisal. The exact query strings were not archived as an appendix. Inclusion was restricted to English-language records, and publication bias is likely. The evidence is small, qualitative, and in part preprint-based, so the synthesis cannot support causal or generalizable claims, and the classification of related records as epistemology-adjacent involves judgment that may change after full-text review.

Future Research

The first priority is to complete the procedures listed as pending in Table 1, namely registered protocol, multi-database search with peer-reviewed strings, independent dual screening, full-text assessment, and MMAT appraisal, and to report the result with a full PRISMA 2020 flow diagram, so that the review can be reclassified as a systematic review. Substantively, longitudinal and comparison-group designs are needed to test whether modeling shifts epistemology, instruments that target model-based epistemology in computational settings should be developed, and the contribution of reflection prompts should be tested directly. Studies at the secondary level and in other cultural contexts are also needed, because no such study was retained here.

CONCLUSION

This preliminary integrative review finds a small, qualitative, and conceptually diverse body of research on computational modeling and epistemology in university physics. The retained evidence shows that epistemic framing and practices can be observed and described in computational modeling settings, and one study reports a shift toward framing a modeling task around physics principles when students troubleshot their simulations. It does not show that computational modeling improves epistemological beliefs, and no retained study tracked change with a stable-beliefs survey. The principal recommendation for instruction is to design modeling tasks in which students test their models against physics principles and to document the epistemic work involved. The principal recommendation for research is to pair theory-explicit designs with instruments and comparison groups

able to detect modeling-related epistemic change. Because the underlying search and screening are incomplete, these conclusions are provisional until the extended systematic review is carried out.

Declaration on the Use of AI Tools

An AI model (Claude, Anthropic) assisted with the preliminary web search, abstract-level screening, and the checking of bibliographic details for this revision. The authors are responsible for the accuracy and interpretation of the content.

REFERENCES

1. Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. Physical Review Special Topics – Physics Education Research, 2, Article 010101. https://doi.org/10.1103/PhysRevSTPER.2.010101
2. Bodin, M. (2012). Mapping university students' epistemic framing of computational physics using network analysis. Physical Review Special Topics – Physics Education Research, 8(1), Article 010115. https://doi.org/10.1103/PhysRevSTPER.8.010115
3. 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
4. Chabay, R., & Sherwood, B. (2008). Computational physics in the introductory calculus-based course. American Journal of Physics, 76(4), 307–313.
5. Giere, R. N. (1999). Science without laws. University of Chicago Press.
6. Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. Journal of Research in Science Teaching, 28(9), 799–822.
7. Hamerski, P. C., McPadden, D., Caballero, M. D., & Irving, P. (2022). Students' perspectives on computational challenges in physics class. Physical Review Physics Education Research, 18(2), Article 020109. https://doi.org/10.1103/PhysRevPhysEducRes.18.020109
8. Hammer, D. (1994). Epistemological beliefs in introductory physics. Cognition and Instruction, 12(2), 151–183.
9. Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), Personal epistemology: The psychology of beliefs about knowledge and knowing (pp. 169–190). Erlbaum.
10. Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. P. Mestre (Ed.), Transfer of learning from a modern multidisciplinary perspective (pp. 89–120). Information Age.
11. Hestenes, D. (1992). Modeling games in the Newtonian world. American Journal of Physics, 60(8), 732–748.
12. Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. Review of Educational Research, 67(1), 88–140.
13. 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.
14. Humphreys, P. (2004). Extending ourselves: Computational science, empiricism, and scientific method. Oxford University Press.
15. Kohlmyer, M. A., Caballero, M. D., & Schatz, M. F. (2011). Working with computational anxiety: Assessing student attitudes towards learning computation [Poster]. Physics Education Research Conference 2011, Omaha, NE, United States.
16. Lane, W. B., & Headley, C. (2022). Student representations of a community of practice. Physical Review Physics Education Research, 18(2), Article 020110.

https://doi.org/10.1103/PhysRevPhysEducRes.18.020110
17. Lunk, B. R., & Beichner, R. J. (2016). Attitudes of life science majors towards computational modeling in introductory physics. In Physics Education Research Conference 2016 (pp. 208–211). American Association of Physics Teachers.
18. McGowan, J., Sampson, M., Salzwedel, D. M., Cogo, E., Foerster, V., & Lefebvre, C. (2016). PRESS Peer Review of Electronic Search Strategies: 2015 guideline statement. Journal of Clinical Epidemiology, 75, 40–46.
19. McHale, S., Odden, T. O. B., & Heller, K. (2026). Same activity, divergent impacts: Representing paths towards physics computational literacy and physics identity with conjecture mapping-based narrative analysis [Preprint]. arXiv. https://arxiv.org/abs/2601.10005
20. Nearhood, L., & Hamerski, P. C. (2025). Student experiences in a computational physics lab through the lens of physics computational literacy. In Physics Education Research Conference 2025 (pp. 314–319). American Association of Physics Teachers. https://doi.org/10.1119/perc.2025.pr.Nearhood
21. Odden, T. O. B., & Caballero, M. D. (2019). Computational essays: An avenue for scientific creativity in physics. In 2019 Physics Education Research Conference Proceedings. American Association of Physics Teachers.
22. Odden, T. O. B., & Zwickl, B. M. (2024). How physics students develop disciplinary computational literacy [Preprint]. arXiv. https://arxiv.org/abs/2403.15028
23. Odden, T. O. B., Lockwood, E., & Caballero, M. D. (2019). Physics computational literacy: An exploratory case study using computational essays. Physical Review Physics Education Research,15(2), Article 020152.
https://doi.org/10.1103/PhysRevPhysEducRes.15.020152
24. 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
25. Perry, W. G. (1970). Forms of intellectual and ethical development in the college years: A scheme. Holt, Rinehart & Winston.
26. Phillips, A. M., Gouvea, E. J., Gravel, B. E., Beauchemin, P.-H., & Atherton, T. J. (2023). Physicality, modeling, and agency in a computational physics class. Physical Review Physics Education Research, 19(1), Article 010121.
https://doi.org/10.1103/PhysRevPhysEducRes.19.010121
27. Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. American Journal of Physics, 66(3), 212–224.
28. Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. Science Education, 89(4), 634–656.
29. Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. Journal of Educational Psychology, 82(3), 498–504.
30. Schwarz, C. V., & White, B. Y. (2005). Metamodeling knowledge: Developing students' understanding of scientific modeling. Cognition and Instruction, 23(2), 165–205.
31. Torraco, R. J. (2005). Writing integrative literature reviews: Guidelines and examples. Human Resource Development Review, 4(3), 356–367.
32. Whittemore, R., & Knafl, K. (2005). The integrative review: Updated methodology. Journal of Advanced Nursing, 52(5), 546–553.
33. Winsberg, E. (2010). Science in the age of computer simulation. University of Chicago Press.