



Implementation of CReW-A Assisted by Video and Interfaces Analysis in Kinematics Learning to Improve Problem-Solving Ability

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Abstract

Problem-solving ability is an essential outcome in physics education, particularly in kinematics where students must connect real motion, graphs, and equations. Although Collaborative Real-World Analysis (CReW-A) assisted by Video and Interfaces Analysis (VIA) has previously been developed and validated as a learning model, rarely study has tested its differential effect on distinct aspects of problem-solving ability. This study tackles that gap by examining students' responses to the implementation of CReW-A assisted by VIA and investigating the improvement of three problem-solving aspects: understanding the problem, planning a strategy, and applying the strategy. The study used a one-group pretest-posttest design involving 31 third-semester students in the Physics Education Study Program, selected through convenience sampling from an intact kinematics class taught over four meetings (uniform motion, uniformly accelerated motion, free fall, and projectile motion). Data were collected using a 10-item response questionnaire (Cronbach's alpha = 0.918) and a 10-item essay test (content validity 93.67%, 'very good'; Cronbach's alpha = 0.698) measuring the three problem-solving aspects. Students' responses were very positive ($M = 4.43$ of 5; 88.52%). The weighted total problem-solving score increased from 27.15 to 71.64 ($N\text{-gain} = 0.61$, medium; paired $t(30) = 11.14$, $p < .001$, $d_z = 2.00$), with the largest gain in applying the strategy ($N\text{-gain} = 0.73$) and medium gains in understanding the problem and planning a strategy. These findings, limited to the studied cohort given the absence of a control group, indicate that CReW-A assisted by VIA is associated with the greatest gains in procedural application of kinematics problem solving, while understanding and planning require additional scaffolding, a pattern carrying direct implications for worksheet and rubric design in physics teacher preparation.

Keywords:

CReW-A; video and interfaces analysis; kinematics; problem solving; prospective physics teachers

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INTRODUCTION

Problem-solving ability is a central learning outcome in physics education because students' understanding of physics is shown not only by recalling concepts but also by identifying situations, selecting representations, planning solution paths, and using mathematical relationships appropriately. In kinematics, students frequently face difficulties interpreting motion graphs, connecting observed motion with variables, and translating graphical information into equations (Beichner, 1994; Jua et al., 2018; Polverini & Gregorcic, 2024). These difficulties indicate that kinematics learning should provide students with opportunities to analyze real motion, coordinate representations, and justify strategies rather than merely practice routine calculations (Iwuanyanwu, 2022; Walsh et al., 2007). Because these graph-interpretation and quantitative-reasoning difficulties are rooted in a lack of concrete referents for motion, addressing them plausibly requires learning activities that let students generate and interpret their own real-motion data rather

than only interpret ready-made graphs, a need that motivates the real-world, video-based analysis component examined in this study. The persistence of this difficulty is also visible locally: prospective physics teachers in the present cohort began the semester with a weighted mean kinematics problem-solving score of only 27.15 out of 100 (see Methods), corroborating that low problem-solving ability in kinematics is not only a literature-reported phenomenon but also an immediate instructional concern.

Collaborative Real-World Analysis (CReW-A) is a six-stage pedagogical model (apperception, introduction, explanation, exercise, presentation, and reflection) developed to respond to this need by means of integrating collaborative activities, real-world data analysis, and guided reflection in physics learning (Firdaus et al., 2020). In this study, CReW-A was implemented with Video and Interfaces Analysis (VIA), the model's technology component, which allows students to record motion phenomena, collect data, generate graphs, and connect empirical data with kinematics concepts using video-tracking and sensor-interface tools such as Logger Pro (Firdaus et al., 2017). The 2017 and 2020 studies that introduced CReW-A and VIA reported model and instrument development together with expert and user validation; neither tested the model's effect on students' problem-solving ability, which is the gap addressed here. Some earlier work on educational technology has used video or sensor tools mainly as supplementary media layered onto otherwise conventional instruction (e.g., Brown & Cox, 2009, illustrating classroom uses of video analysis as an add-on activity), whereas CReW-A embeds VIA within a structured, staged instructional syntax. More broadly, studies on video analysis, multiple representations, and physics problem solving show that technology becomes more productive when it is embedded in coherent pedagogy, collaborative tasks, and explicit reasoning activities (Becker et al., 2020; Beichner, 1996; Hochberg et al., 2020; Kohl & Finkelstein, 2006; Kulgemeyer et al., 2022; Listiaji et al., 2020; Worner et al., 2021), though most of these studies report engagement or overall procedural gains without disaggregating problem-solving into conceptual, strategic, and procedural components.

The combination of CReW-A and VIA is grounded in three complementary theoretical perspectives. First, constructivist learning theory suggests that students build physics understanding by connecting prior knowledge with real-world motion data, graphs, equations, and peer explanations (Hmelo-Silver, 2004; Sirnoorkar et al., 2023). Second, social interdependence theory explains why collaborative work can support problem solving: positive interdependence and promotive interaction help students share representations, test ideas, and refine solution procedures (Brand et al., 2023; Brundage et al., 2023; Heller & Hollabaugh, 1992; Johnson & Johnson, 2009; Pulgar et al., 2021; Xu et al., 2023). Third, cognitive load theory supplies a rationale for structuring VIA activities through demonstration, guided exercise, presentation, and reflection so that videos, graphs, and equations reduce unnecessary processing and support schema construction rather than overwhelming working memory (Hochberg et al., 2020; Paas & van Merriënboer, 2020; Sweller et al., 2019). These three perspectives are not independent additions but map onto distinct components of the CReW-A/VIA syntax and are expected to shape the pattern of aspect-level gains reported in Results jointly: constructivism accounts for how VIA's real, self-collected motion data grounds students' understanding of the problem and their planning of a solution strategy; social interdependence accounts for how the model's collaborative stages (introduction, exercise, and presentation) support the sharing and refinement of representations and strategies; and cognitive load theory accounts for how the staged sequencing of demonstration, guided exercise, and reflection manages the

processing demands of operating VIA tools while applying a chosen strategy, a component expected to benefit most directly from procedural repetition.

Although CReW-A and VIA have been developed and validated in previous work (Firdaus et al., 2017, 2020), evidence is still needed on how the model affects particular aspects of problem-solving ability in an authentic kinematics course for prospective physics teachers. Studies such as Gumisirizah et al. (2024) and Manurung and Panggabean (2020) show that problem-based learning and interactive multimedia can improve problem solving, and the technological pedagogical content knowledge framework similarly stresses incorporating technology with pedagogy and content (Mishra & Koehler, 2006); however, these studies evaluate problem solving as a single composite outcome rather than testing whether conceptual (understanding), strategic (planning), and procedural (applying) dimensions respond differently to instruction, and no prior CReW-A or VIA study has disaggregated its effect in this way. If effects genuinely differ across these dimensions, aggregate outcome measures risk masking exactly the information instructors need to target scaffolding. This is the specific, non-redundant contribution of the present study. This article therefore examines students' responses to the implementation of CReW-A assisted by VIA and analyzes the improvement of three measured aspects of problem solving: understanding the problem, planning a strategy, and applying the strategy. Theoretically, the study expands the constructivist-social-interdependence-cognitive-load integration described above by identifying which problem-solving component benefits most from real-data video analysis; practically, it informs how worksheets, rubrics, and instructional time should be allocated in physics teacher preparation. The study delivers empirical evidence on which aspects improve most strongly and provides practical implications for strengthening kinematics instruction.

The novelty of this article is that it is the first study to report the differential effect of CReW-A assisted by VIA on three separable aspects of problem-solving ability (understanding the problem, planning a strategy, and applying the strategy) in an authentic kinematics course for prospective physics teachers, rather than reporting problem solving as a single composite score as in prior CReW-A/VIA work (Firdaus et al., 2017, 2020) and in related technology-integration studies (Gumisirizah et al., 2024; Manurung & Panggabean, 2020). Unlike studies that use video or sensor tools mainly as supplementary media layered onto conventional instruction, this study positions VIA as part of a structured, staged learning syntax (CReW-A) in which collaborative, real-world data collection is integral to every stage rather than an optional add-on.

METHODS

Research Design

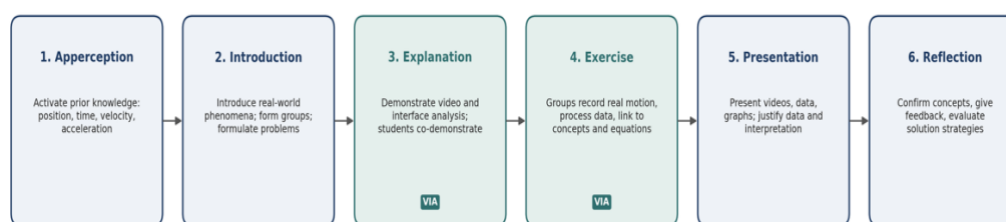
A one-group pretest-posttest design was employed to measure students' problem-solving ability before and after instruction using the CReW-A model, assisted by VIA. This approach was selected due to the availability of only one intact kinematics section during the semester, which precluded the formation of a parallel comparison group within the same cohort and timeframe. The design is suitable for providing preliminary evidence of change following an intervention. Some threats to internal validity were mitigated by employing the same instructor and instrument for the entire cohort and by restricting the intervention to a brief, four-meeting period to limit maturation effects. Nevertheless, testing effects and history remain possible confounding factors, and the lack of a control group prevents attributing observed gains solely to the intervention. This limitation is addressed further in the Conclusion.

Participants and Context

Participants consisted of 31 third-semester students enrolled in the Physics Education Study Program at a single institution in South Sumatra, Indonesia. Convenience sampling was employed, as the sample comprised a single intact kinematics class accessible to the researchers and directly exposed to the implemented learning model. This pragmatic constraint limits the generalizability of the findings primarily to similarly structured cohorts of prospective physics teachers, rather than to a broader or randomly sampled population. The group exhibited uniformly low problem-solving ability at baseline, as indicated by a weighted pretest mean of 27.15 (SD = 18.66) on a 0-100 scale.

Implementation of the CReW-A Model Assisted by VIA

The CReW-A model assisted by VIA was implemented across four meetings, each addressing a distinct kinematics topic: uniform motion, uniformly accelerated motion, free fall, and projectile motion. The pretest was administered before the first meeting, and the posttest followed the fourth meeting. Each session adhered to six structured stages. The apperception stage reviewed prior knowledge relevant to kinematics, including position, time, velocity, and acceleration. The introduction stage engaged students with everyday physics phenomena and organized them into working groups, prompting the formulation of problems based on observed motion. The explanation stage provided instruction on video and interface analysis, with both lecturer-led and student-involved demonstrations to enhance independent analytical skills. During the exercise stage, students collaborated to record videos of real-world kinematics phenomena, process data, and relate their analyses to physics concepts and equations. The presentation stage facilitated the sharing of videos, data, graphs, and analysis results, with students articulating their rationale for phenomenon selection, data collection methods, and physics interpretations. The reflection stage reinforced key concepts, offered feedback, and evaluated problem-solving strategies. Collectively, these stages were designed to integrate concrete experiences, data representation, collaborative discussion, and conceptual reflection. Figure 1 summarizes this process, highlighting the role of VIA in the explanation and exercise stages.



Note: VIA (Video and Interfaces Analysis) is emphasized in the explanation and exercise stages.

Figure 1. Syntax of the CReW-A model assisted by VIA

Research Instruments

The primary instrument was an essay test assessing kinematics problem-solving ability. The test design was informed by Polya's four-stage problem-solving framework:

understanding the problem, devising a plan, carrying out the plan, and evaluating the solution (Heller et al., 1992; Lorenzo, 2005; Walsh et al., 2007). In physics education, these stages are typically operationalized through rubrics that evaluate students' abilities to represent problems, plan solution strategies, apply physics and mathematics, and assess the reasonableness of their answers (Docktor & Mestre, 2014; Docktor et al., 2016).

The test comprised 10 essay items distributed across three analytically distinct aspects: understanding the problem (2 items, maximum 6 points), planning a strategy (3 items, maximum 7 points), and applying the strategy (5 items, maximum 11 points). Each item was scored using a partial-credit rubric adapted from Docktor and Mestre (2014) and Docktor et al. (2016), with point allocations reflecting the complexity of the response required. Aspect-level and total scores were calculated as weighted percentages (see Data Analysis). Content validity was established by three subject-matter experts, who rated the instrument's alignment with the material at 100%, the indicators at 89.81%, and the answer key at 91.20%, resulting in a mean content-quality score of 93.67% ('very good' according to Riduwan's (2012) criteria). Empirical item validity was determined via Pearson product-moment correlation in a trial with 36 physics education students not included in the main study, yielding item coefficients from moderate to high ($r = 0.446-0.757$). Instrument reliability was Cronbach's $\alpha = 0.698$, which is considered acceptable (Gall et al., 2003). Scoring was conducted by a single rater, and the absence of inter-rater reliability data is acknowledged as a limitation (see Conclusion). Although Polya's framework includes a fourth stage (evaluation or 'looking back'), the instrument was intentionally limited to the three aspects described. The evaluation process was embedded within students' written reasoning across these aspects, rather than being assigned a separate rubric. This design decision was made to preserve data integrity and avoid retrospective score reconstruction; developing a validated rubric for the evaluation stage is identified as a priority for future revisions.

Students' responses to the implementation of CReW-A assisted by VIA were measured using a five-point Likert-scale questionnaire consisting of 10 positive statements. The questionnaire covered the clarity of learning stages, clarity of media guidance, usefulness of worksheets, relevance to real kinematics phenomena, support for everyday problem solving, creativity in decision making, graph and equation analysis, group work, educational technology knowledge, and the usefulness of Logger Pro and sensor interfaces.

Data Analysis

Problem-solving ability data were analyzed using the mean, standard deviation, absolute gain, N-gain, paired-samples t-test, and Cohen's d_z effect size. The weighted score for each aspect and for the total score was calculated as the sum of raw scores obtained across the relevant items divided by the sum of the maximum attainable scores for those items, multiplied by 100. Before the paired-samples t-test was conducted, the normality of the pretest-posttest difference scores was checked with the Shapiro-Wilk test. The difference scores for each of the three aspects were normally distributed (understanding the problem, $p = .130$; planning a strategy, $p = .117$; applying the strategy, $p = .232$), while the composite total-score difference showed borderline deviation from normality ($W = 0.931$, $p = .047$); as a robustness check, a Wilcoxon signed-rank test was additionally conducted on the total score and corroborated the same conclusion as the paired t-test ($p < .001$). N-gain was calculated as the difference between posttest and pretest scores divided by the difference between the maximum score and the pretest score. The N-gain categories used were high if $g \geq 0.70$, medium if $0.30 \leq g < 0.70$, and low if $g < 0.30$ (Hake, 1998). Students were classified as reaching the minimum passing score (KKM) of 70 stipulated in

the Physics Education Study Program's curriculum guideline. Student response data were analyzed using the mean, percentage, standard deviation, score distribution, and internal reliability; percentage scores were interpreted using Riduwan's (2012) criteria ($\geq 80\%$ = very good, 60-79% = good, 40-59% = fair, 20-39% = low, $< 20\%$ = very low).

RESULTS & DISCUSSION

Result

Student Responses to the Implementation of CReW-A Assisted by VIA

Students perceived the implementation of CReW-A assisted by VIA very positively. The overall mean response was 4.43 on a 5-point scale (88.52%), which falls into the very good category following the criteria described in Data Analysis (Riduwan, 2012). The internal reliability of the response questionnaire was high (Cronbach's $\alpha = 0.918$), indicating that the questionnaire items had strong consistency. Because these are self-report Likert data, the results should be interpreted as evidence of students' perceived acceptability of the model rather than as direct evidence of improved creativity, teamwork, or technological knowledge, and the possibility of social-desirability or response bias cannot be ruled out. Table 1 presents the item-level response data, and Figure 2 visualizes the percentage of each questionnaire item.

Table 1. Student Responses to the Implementation of CReW-A Assisted by VIA

No	Statement Aspect	Mean	SD	Percentage (%)
1	The stages of the kinematics course program are easy to understand	4.29	0.74	85.81
2	The guide and media explanations are easy to understand	4.39	0.67	87.74
3	The material in the student worksheet helps students understand concepts	4.68	0.48	93.55
4	The learning helps students understand natural phenomena related to kinematics	4.35	0.66	87.10
5	The learning helps students solve everyday problems related to kinematics	4.32	0.79	86.45
6	The learning encourages creativity in decision making	4.55	0.57	90.97
7	The learning increases knowledge of graph and equation analysis	4.32	0.60	86.45
8	The learning strengthens group work	4.29	0.59	85.81
9	The learning broadens knowledge of learning technology	4.52	0.63	90.32
10	Logger Pro and Sensor Interfaces help students understand kinematics concepts	4.55	0.62	90.97
Overall mean		4.43	0.48	88.52

The highest-rated item was the statement that the student worksheet facilitated conceptual understanding (93.55%), followed by items regarding encouragement of creativity in decision-making and the benefits of Logger Pro/Sensor Interfaces (90.97% each). These results suggest that students viewed the model favorably not only in procedural aspects but also in its benefits for conceptual understanding, technology integration, and problem-solving. Figure 2 illustrates that all questionnaire items exceeded 85% of the maximum score.

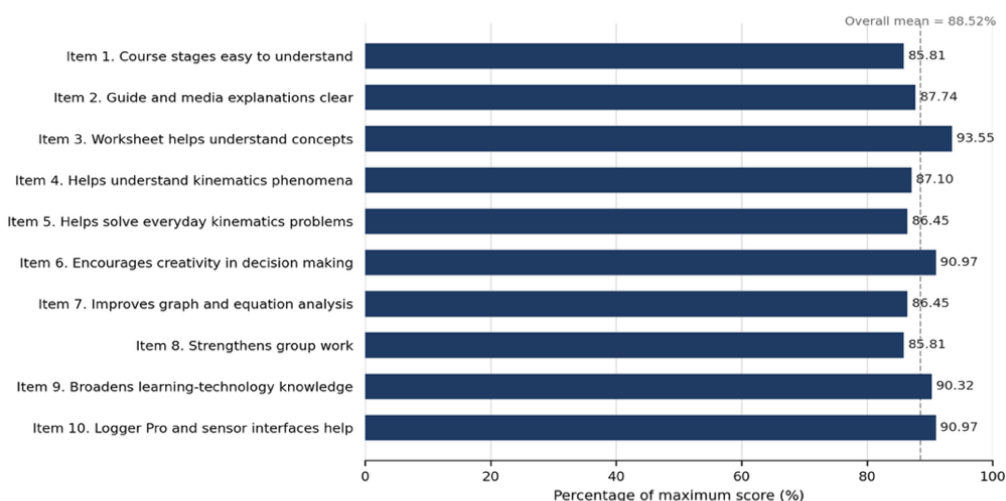


Figure 2. Student response percentage for each questionnaire item.

Improvement in Problem-Solving Ability

Problem-solving ability improved across all measured aspects following instruction with CReW-A assisted by VIA. The weighted total score increased from a mean of 27.15 in the pretest to 71.64 in the posttest (see Data Analysis for calculation details). The absolute gain was 44.49 points, with an N-gain of 0.61, categorized as medium. A paired-samples t-test, with normality assumptions verified as described in Data Analysis, indicated a statistically significant difference between pretest and posttest scores, $t(30) = 11.14$, $p < .001$, and a large within-group effect size ($d_z = 2.00$). Given the one-group design, this effect size represents the magnitude of change from pretest to posttest and does not indicate superiority over alternative instructional methods.

Table 2. Improvement in Students' Problem-Solving Ability

Aspect	Pretest M	Pretest SD	Posttest M	Posttest SD	Gain	N-gain	Category	t(30)	p	d _z
Understanding the problem	24.19	14.81	58.07	21.14	33.87	0.45	Medium	7.09	<0.001	1.27
Planning strategy	38.25	37.51	71.43	17.59	33.18	0.54	Medium	4.85	<0.001	0.87
Applying the strategy	21.70	15.51	79.18	14.46	57.48	0.73	High	13.14	<0.001	2.36
Weighted total	27.15	18.66	71.64	11.19	44.49	0.61	Medium	11.14	<0.001	2.00

The greatest improvement occurred in the aspect of applying the strategy, with an N-gain of 0.73 in the high category. This indicates that after participating in the learning process, students were better able to use theories or equations to solve kinematics problems. The aspects of understanding the problem and planning a strategy also improved in the medium category. Individually, the total N-gain categories consisted of 4 students in the low category, 16 students in the medium category, and 11 students in the high category. In the posttest, 15 of the 31 students achieved a minimum weighted total score of 70 (KKM; see Data Analysis). Figure 3 compares the pretest and posttest scores, Figure 4 displays the N-gain values by aspect, and Figure 5 shows the distribution of students' individual N-gain categories.

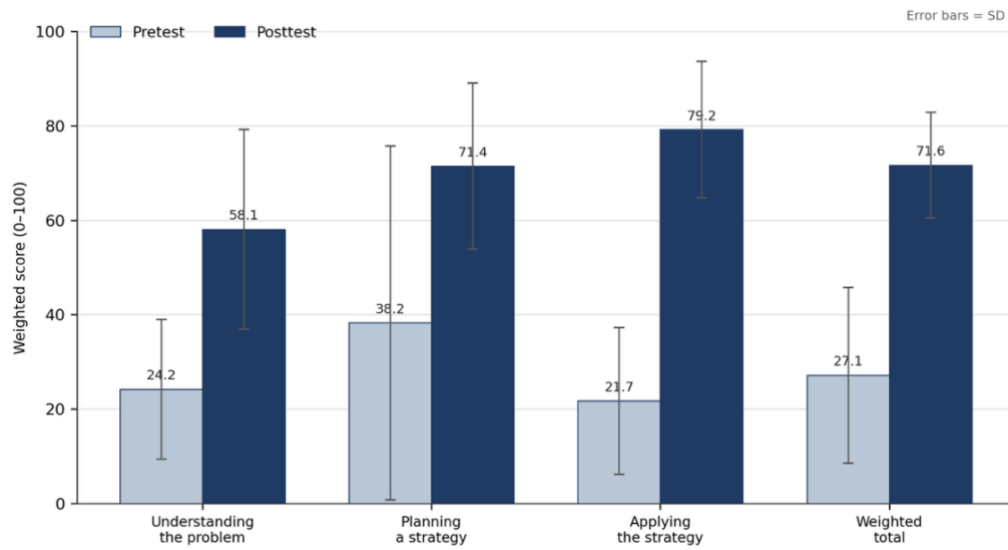


Figure 3. Comparison of pretest and posttest scores for problem-solving ability

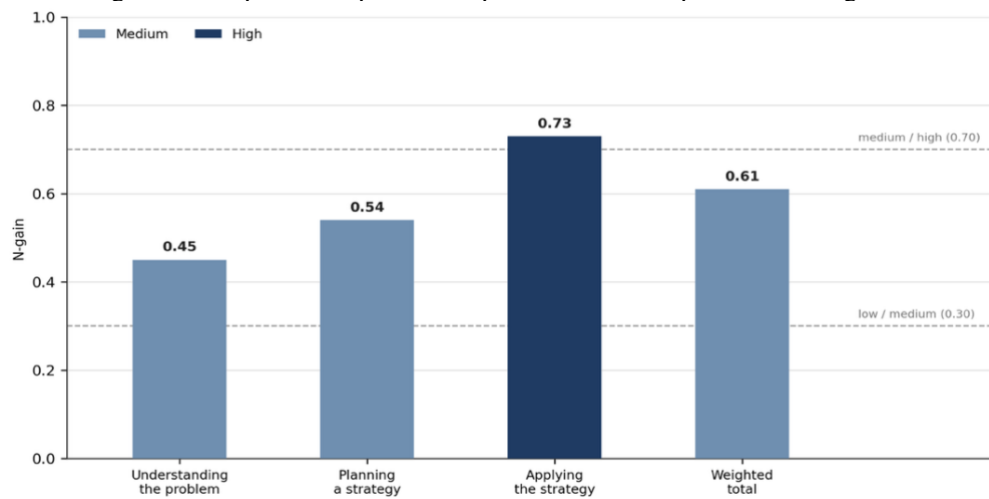


Figure 4. N-gain of problem-solving ability by aspect and total score.

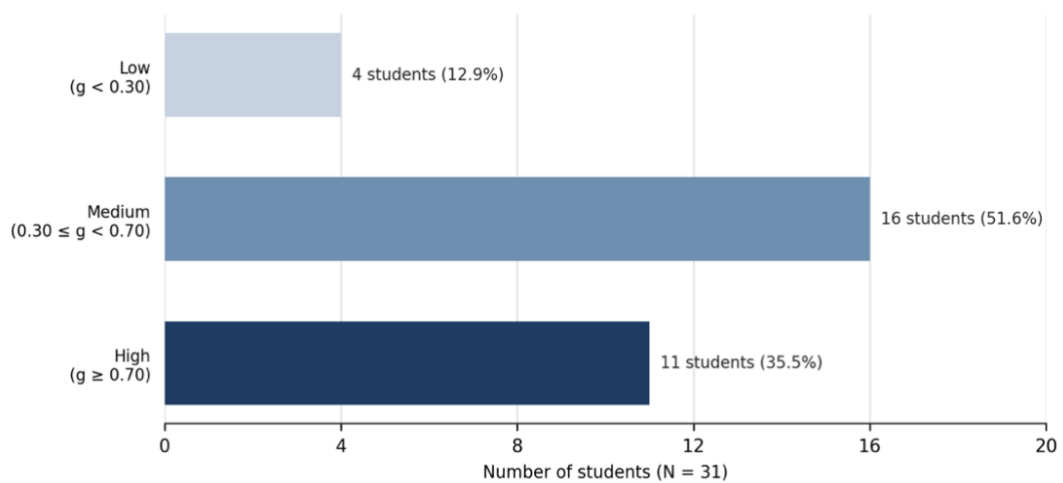


Figure 5. Distribution of students' individual N-gain categories

Discussion

The findings indicate that CReW-A, when assisted by VIA, led to improvement across all measured aspects of problem-solving ability. The weighted total score increased from 27.15 to 71.64, with an N-gain of 0.61 and a large effect size. This outcome suggests that integrating collaborative real-world analysis with technology-supported motion analysis enables prospective physics teachers to progress from fragmented kinematics knowledge to more effective problem-solving performance. These results align with existing evidence that active learning, guided problem solving, and multiple-representation activities enhance learning in physics and other STEM disciplines (Burkholder et al., 2022; Docktor & Mestre, 2014; Freeman et al., 2014; Theobald et al., 2020).

The strongest improvement occurred in applying the strategy. This result is reasonable because the exercise and presentation stages of CReW-A directly trained students to carry out solution procedures using real data. Through VIA, students repeatedly transformed recorded motion into position-time or velocity-time graphs, identified gradients or trends, selected equations, substituted values, and checked whether the numerical result matched the observed motion. Such activities give students procedural anchors: they see where variables come from, why a graph has a particular form, and how equations operate on empirical data. In this sense, VIA may provide stronger support for carrying out a selected strategy than for initially framing the problem. Similar mechanisms are reported in studies showing that video analysis and interactive video-enhanced tutorials can improve students' ability to coordinate motion data, graphs, and quantitative reasoning (Beichner, 1996; Hochberg et al., 2020; Koenig et al., 2022; Worner et al., 2021).

The moderate improvement in understanding the problem and planning a strategy indicates where scaffolding should be strengthened in future implementations. Understanding a problem requires students to identify relevant information, distinguish known and unknown variables, recognize the physical situation, and choose an appropriate representation before using equations. Planning a strategy requires a further step: selecting a coherent route from the representation to the solution. These aspects are conceptually demanding because students must decide what matters before calculation begins. In the present implementation, the VIA tools made data and graphs visible, but visibility alone does not guarantee that students will formulate the problem deeply or compare alternative strategies. Without explicit prompts for variable identification, assumptions, representation choice, and plan justification, some students may have moved quickly from the graph to formula use.

Cognitive load theory offers one plausible interpretation of this pattern, though it should be treated as a hypothesis rather than an established mechanism because cognitive load was not directly measured in this study. Under this interpretation, video analysis may reduce extraneous load by making motion data visible, yet it could also introduce additional processing demands when students must operate software, interpret graphs, discuss in groups, and solve problems at the same time (Paas & van Merriënboer, 2020; Sweller et al., 2019). For students with low initial ability, the most immediately learnable element may be the repeated procedure of applying equations to data, while the more abstract tasks of understanding and planning could require slower schema development. Future studies should test this interpretation directly using a validated cognitive load instrument (e.g., the Paas scale). In the meantime, future implementation could include more explicit worked examples, comparison of alternative plans, and short reflection prompts before students proceed to calculation, which would align the technology with conceptual and strategic reasoning rather than letting procedural application dominate the learning episode.

The very positive student response supports the feasibility of implementing CReW-A assisted by VIA in kinematics learning. Students rated the model highly because worksheets, real phenomena, Logger Pro, sensor interfaces, and group activities helped them connect kinematics concepts with observable motion. However, positive response should be interpreted as acceptability rather than direct evidence of effectiveness. The response data explain why students were willing to engage with the model, while the pretest-posttest data show measurable improvement in problem-solving ability. Together, the two forms of evidence suggest that CReW-A assisted by VIA is both pedagogically acceptable and empirically promising for a prospective physics teacher context.

Several limitations remain. The study used a one-group pretest-posttest design with one intact class and no control group, so testing effects, history, and maturation cannot be fully ruled out, and improvement cannot be attributed solely to the intervention. The sample was limited to 31 students from one study program at one institution, selected through convenience sampling, which restricts generalizability to similarly structured cohorts rather than to a broader population. The essay test was scored by a single rater without independent second scoring, so inter-rater reliability could not be established. The problem-solving analysis also covered only three of Polya's four stages by design, as the evaluation or looking-back stage was not assigned an independent scoring rubric in this instrument. Even so, the findings are useful for lecturers because they identify a specific instructional pattern, associated with (rather than necessarily caused by) the intervention: VIA appears especially powerful for supporting application of strategies, but understanding and planning require more deliberate scaffolding. Curriculum developers can therefore integrate CReW-A with rubrics, worksheets, and assessment tasks that explicitly require students to state what is known, justify representations, compare plans, and evaluate the reasonableness of solutions.

CONCLUSION

In the studied cohort, the implementation of CReW-A assisted by Video and Interfaces Analysis was associated with improvement across all three measured aspects of prospective physics teachers' problem-solving ability, with the largest gain in applying the strategy (N-gain = 0.73) and medium gains in understanding the problem and planning a strategy (weighted total score: 27.15 to 71.64; N-gain = 0.61). The study's specific contribution is identifying this differential pattern across problem-solving aspects rather than reporting a single composite outcome, and showing that procedural application, not conceptual understanding or strategic planning, benefited most from the model as implemented. These findings are limited to the single intact cohort studied here and should not be generalized beyond similarly structured prospective-physics-teacher contexts, given the one-group design without a control group, the convenience sample of 31 students from one institution, single-rater essay scoring without inter-rater verification, and the exclusion of the evaluation/looking-back stage from the scoring rubric. Practically, physics lecturers can use CReW-A assisted by VIA by allocating explicit scaffolding time for identifying variables, selecting representations, and planning equations before students work intensively with VIA-generated graphs; curriculum developers can embed these scaffolds into worksheets and assessment rubrics so that procedural gains are accompanied by stronger conceptual and strategic gains. Future research should use a comparison group, involve a larger sample across institutions, establish inter-rater reliability for essay scoring, and develop a rubric that measures all four problem-solving stages, including evaluation or looking back, as an independent aspect.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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