Phi: Jurnal Pendidikan Fisika dan Terapan
Vol.12 No.2 (2026) 103-115
ISSN: 2460-4348, e-ISSN: 2549-7162
https://jurnal.ar-raniry.ac.id/index.php/jurnalphi/index

Article Type: *original research*

Effects of the ARCS Instructional Model on Undergraduate Students' Motivation and Learning Outcomes in an Online Basic Physics Course

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ARTICLE INFO

Article History:
Received: 11 December 2025
Revised: 07 May 2026
Accepted: 10 May 2026
Published: 24 May 2026

Keywords:
ARCS; Learning Motivation; Learning Outcomes

ABSTRACT

This study investigates the effectiveness of the ARCS motivational model (Attention, Relevance, Confidence, Satisfaction) in improving undergraduate students' motivation and learning outcomes in an online Basic Physics course. A one-shot case study design was employed with a single cohort of students ($n = 37$). Learning motivation was measured using a validated ARCS-based questionnaire, while learning outcomes were assessed through a post-test aligned with four Sub-CPMK indicators. Descriptive statistics and the Wilcoxon signed-rank test were used to analyze the data. The Wilcoxon test compared students' post-test scores against the predetermined minimum competency standard (KKM = 70). Results showed generally high levels of motivation across most indicators (61.95%–80.26%), although engaging learning activities fell within the moderate category (53.78%). Learning outcomes varied substantially, with the highest performance recorded in Sub-CPMK 3 (analyzing motion through data, graphs, and equations) at 83.2%, and the lowest in Sub-CPMK 2 (vector analysis and dipole moment concepts) at 14.6%. The Wilcoxon signed-rank test yielded a significant result ($p = 0.000$), indicating that student performance significantly exceeded the KKM benchmark. These findings suggest that the ARCS model effectively enhances motivation and conceptual understanding, particularly for visually representable content, while highlighting the need for additional instructional scaffolding (e.g., progressive visual support and guided practice) to improve learning of abstract concepts such as vectors and dipole moments. Future research is recommended to employ stronger experimental controls (e.g., pretest-posttest control group designs) and item-level analyses to further validate the applicability of the ARCS model in online physics education.

1. INTRODUCTION

The rapid digital transformation of higher education has positioned online learning as a permanent and strategic mode of instruction, yet its effectiveness is often undermined by a critical problem: declining student motivation. In disciplines such as Basic Physics, which demands abstract reasoning, conceptual integration, and quantitative problem-solving, the shift to online environments has exacerbated students' difficulties. Without the direct guidance of laboratory work and real-time instructor feedback, many undergraduates struggle to sustain attention, perceive the relevance of abstract concepts, and build confidence in their analytical skills (Wiseman, et al., 2020 ;Brahmia et al., 2021). Studies conducted during and after the COVID-19 pandemic revealed that up to 60% of students in STEM courses reported lower engagement in online compared to face-to-face settings (Wester, et al., 2021), This motivation deficit is not merely an affective issue; it directly predicts surface learning strategies, poor knowledge retention, and unsatisfactory learning outcomes, particularly in foundational physics topics such as vector analysis, dimensional reasoning, and Newtonian mechanics (Wilcox, et al 2020; Betari et al., 2021)

To address motivational challenges in instructional design, John Keller's ARCS model (Attention, Relevance, Confidence, Satisfaction) has been widely validated as an effective framework for enhancing both intrinsic and extrinsic motivation across various educational levels. The model provides concrete strategies—such as varying presentation methods, connecting content to real-world applications, scaffolding tasks to build self-efficacy, and offering meaningful reinforcement—that are particularly suitable for online learning environments (Fang et al., 2024; Doo, et al., 2020). Meta-analyses have confirmed that ARCS-based interventions significantly improve learner engagement and academic achievement, with effect sizes ranging from moderate to large in science education. Moreover, recent adaptations of ARCS for digital platforms, including intelligent tutoring systems and gamified modules, have demonstrated that its components can be effectively operationalized through interactive media, simulations, and structured feedback loops (Maiti, et al., 2023).

However, despite this body of evidence, several research gaps remain conspicuously unaddressed. First, the majority of ARCS studies in science education have been conducted at the secondary or junior high school level, leaving undergraduate education—especially introductory physics courses for non-physics majors—severely under-researched. Second, existing studies often treat online learning as a generic setting without specifying the disciplinary context; the unique cognitive demands of Basic Physics (e.g., understanding vectors, dipole moments, motion graphs) are rarely integrated into the motivational design or outcome measurement. Third, and most critically, prior research has typically reported global or averaged effects on motivation and learning outcomes, overlooking the differential performance across specific sub-topics or cognitive indicators (Sub-CPMKs). This coarse-grained analysis masks valuable information about which aspects of a subject benefit most from ARCS and which remain resistant, even after motivational intervention. As a result, instructors lack actionable guidance on where to strengthen scaffolding or adjust instructional strategies.

The present study directly addresses these gaps by offering three interconnected novelties. First, it focuses on an authentic undergraduate Basic Physics course delivered entirely online, a context that has received minimal empirical attention despite its prevalence in Indonesian higher education. Second, instead of relying solely on aggregate scores, this study conducts a detailed Sub-CPMK-level analysis of learning outcomes, measuring student performance across four distinct competency indicators: applying measurement concepts (Sub-CPMK 1), analyzing vectors and dipole moments (Sub-CPMK 2), interpreting motion through data and graphs (Sub-CPMK 3), and applying Newton's laws (Sub-CPMK 4). This granular approach allows the identification of specific topics where ARCS is highly effective versus those where additional scaffolding is necessary. Third, the study isolates the ARCS model as a standalone motivational intervention—free from confounding integration with other pedagogies such as PjBL—thereby providing a cleaner test of its direct effect in an online setting enriched with interactive simulations and collaborative activities. By doing so, the research strengthens the causal interpretability of findings and offers a replicable framework for future studies.

Therefore, this study aims to investigate the effectiveness of the ARCS model in improving both motivation and learning outcomes in an online Basic Physics course for undergraduate students, while specifically examining how performance varies across Sub-CPMK indicators. The central research questions are: (1) To what extent does the ARCS model increase student motivation compared to conventional online instruction? and (2) How does student learning outcome differ across cognitive sub-competencies after ARCS-based instruction? By answering these questions, this research contributes empirical evidence for the targeted application of motivational design in higher education physics, informs the development of adaptive scaffolding for abstract topics, and provides a methodological model for future studies seeking to evaluate instructional interventions at the sub-competency level. The findings are expected to guide lecturers and curriculum designers in creating more responsive and effective online learning environments, particularly in conceptually demanding STEM disciplines.

2. METHODS

This study employed a quantitative pre-experimental design, specifically a one-shot case study design. This design was chosen over a quasi-experimental or true experimental design because the study aimed to evaluate the effectiveness of the ARCS instructional model on students' motivation and learning outcomes in a real-world online classroom setting without disrupting existing course structures or denying any student access to the potentially beneficial intervention.

2.1 Research Design

This study employed a One-Shot Case Study design, a pre-experimental method in which a single group receives an instructional intervention followed by a post-test. The design was chosen to capture the immediate effects of the ARCS intervention on students' motivation and learning outcomes in an online Basic Physics course. While the absence of a comparison group limits the ability to draw strong causal conclusions, the approach remains useful for examining instructional feasibility and identifying early signs of effectiveness in real classroom settings. This type of design is well suited for exploratory research, especially in situations where instructional innovations must be implemented within naturally existing groups without disrupting the established course structure. The overall research design is summarized.

2.2 Population and Sample

The research population comprised all first-semester undergraduate students enrolled in the Chemistry Education Study Program at the University of Lampung who were taking the mandatory Basic Physics course during the even semester of the 2024/2025 academic year. From this population, a single intact class was selected using purposive sampling based on the following criteria: (a) students had not previously received instruction using the ARCS model in any physics course, (b) the course schedule allowed for the full 8-week intervention, and (c) students voluntarily agreed to participate in the study.

A total of 37 students were initially enrolled in the target class. All 37 students consented to participate and completed the full 8-week intervention, resulting in a 100% participation rate (no attrition). The final sample size was therefore N = 37.

2.3 Instruments

Students' motivation was assessed using a 25-item questionnaire developed based on the ARCS motivational design model (Keller, 2010). The instrument measured five indicators derived from the ARCS framework: (1) desire to succeed, (2) learning drive and needs, (3) appreciation toward learning, (4) conduciveness of the learning environment, and (5) engaging learning activities. Each indicator was represented by five items, yielding a total of 25 items. All items were rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree).

The questionnaire underwent content validation through expert judgment by two doctoral-level physics educators, who assessed item clarity, relevance, and alignment with the ARCS components. A pilot test conducted with 20 students (not part of the main sample) yielded a Cronbach's alpha of 0.89, indicating high internal consistency.

2.4 Data Analysis

The learning outcome test consisted of 20 multiple-choice and structured response items distributed across four Sub-CPMK competencies (5 items each). A grid of specifications was developed to ensure content representativeness, mapping each item to a specific Sub-CPMK, a cognitive level based on Bloom's revised taxonomy (C1 = remembering, C2 = understanding, C3 = applying, C4 = analyzing), and the intended score weight. Specifically, Sub-CPMK 1 (applying significant figures and dimensional analysis) included two C2 items and three C3 items; Sub-CPMK 2 (vector resolution and dipole moments) comprised one C2, two C3, and two C4 items; Sub-CPMK 3 (motion analysis using data, graphs, and equations) contained two C3 and three C4 items; and Sub-CPMK 4 (Newton's laws in multi-body systems) included three C3 and two C4 items. Each correct answer was awarded a score of 1, yielding a total score range from 0 to 20 (converted to a 0–100 scale). Content validation was performed by two physics education experts, who rated each item for relevance, clarity, and alignment with the Sub-CPMKs. The content validity index (CVI) based on expert ratings was 0.92. The test was pilot-tested on 20 students from a similar population, and reliability was estimated using the Kuder-Richardson formula (KR-20), producing a coefficient of 0.81, indicating good internal consistency.

Data analysis was carried out using both descriptive and inferential statistical techniques. Descriptive statistics (mean scores, percentages, and standard deviations) were used to summarize students' motivation across the ARCS indicators and to describe their performance on the four Sub-CPMK competencies. A normality test using the Shapiro–Wilk method showed that the learning outcomes data were not normally distributed ($p = 0.002$), which led to the use of the non-parametric one-sample Wilcoxon signed-rank test to determine whether students' post-test scores significantly surpassed the minimum competency threshold (KKM = 70). Additional analysis at the Sub-CPMK level was conducted to identify patterns in students' conceptual mastery across competencies that varied in cognitive complexity. Motivation scores were converted into percentage values and categorized into high, medium, and low levels to provide a clearer interpretation of students' motivational profiles. Together, these analytical procedures were employed to assess the initial effectiveness of the ARCS model in supporting motivation and conceptual learning within an online Basic Physics environment.

3. RESULT AND DISCUSSION

3.1 Score Conversion and Descriptive Overview

The results of this study offer a clear overview of how the ARCS motivational approach shapes students' learning outcomes and motivation in a Basic Physics course. The learning outcome test consisted of 20 items, each scored dichotomously (1 = correct, 0 = incorrect). The raw score (0–20) was converted to a percentage scale using the formula: Percentage = (Raw score / 20) × 100. The institutional minimum competency standard (KKM) was set at 70%, equivalent to 14 correct answers. Table 1 presents the descriptive statistics for each Sub-CPMK indicator after conversion to percentages. Motivation questionnaire items used a 5-point Likert scale (1–5); total scores per indicator were summed and interpreted as percentages of the maximum possible score.

The learning-outcome data reveal differences in achievement across competencies, with the strongest results appearing in motion-analysis tasks (80%), moderate performance in measurement and numerical reasoning (57–66%), and the lowest scores in more abstract areas such as vector resolution and dipole-moment concepts (55%). These patterns are consistent with previous findings showing that student performance in physics often varies across representational and conceptual domains, where tasks involving visual or analytical representations are generally easier to grasp than abstract conceptual content (Edelsbrunner et al., 2023; Jane, 2026; Evagorou, et al., 2015) The strong performance in analytical tasks also indicates that the ARCS approach successfully enhanced the Attention and Relevance components by linking learning to real-world contexts, visual models, and clearly defined objectives (Afjar, et al., 2020; Pramitha, et al., 2025). Descriptive statistics were used to provide an initial picture of the data, summarizing minimum and maximum values, means, medians, and standard deviations to illustrate distribution patterns and variability before further analysis. The detailed statistical results for each indicator of learning outcomes and motivation are presented in Table 2 and Table 3.

Table 1. Learning Outcome Indicators Data

Learning Outcome Indicator	Max	Min	Mean	SD
Sub-CPMK 1: Applying the Concept of Significant Figures and Dimensions in Measurement and Chemical-Physical Calculations	28	5	35.2	0.59
Sub-CPMK 2: Analyzing Properties and Calculating Vector Resultants in the Context of Force and Dipole Moment	13	3	22.7	0.35
Sub-CPMK 3: Analyzing Object Motion in Various Conditions Through Data, Graphs, and Mathematical Equations	22	7	65.2	0.56
Sub-CPMK 4: Applying Newton's Laws to Analyze Forces and Motion in Object Systems	19	9	24.8	0.51

Table 2. Motivation Indicator Data

Motivation Indicators	Max	Min	Mean	SD
Desire and Willingness to Succeed	18	13	14.87	1.19
Encouragement and Need in Learning	12	8	10.32	0.77
Appreciation in Learning	8	4	5.11	0.73
Conducive Learning Environment Allowing Students to Learn Well	14	10	12.84	1.03
Interesting Activities in Learning	10	6	8.61	0.95

This study was designed to answer two primary research questions: (1) To what extent does the ARCS model increase student motivation compared to conventional online instruction? and (2) How does student learning outcomes differ across cognitive sub-competencies after ARCS-based instruction? The results provide partial answers to both questions while also revealing important pedagogical insights.

In addition to the numerical results presented in Tables 2 and 3, the diagrams illustrating learning outcomes and motivation offer a clearer picture of how students responded to the instructional process. These visualizations complement the quantitative analysis by showing more detailed patterns through percentage-based comparisons. The bar chart displaying students' learning outcomes (Figure 1) reveals noticeable variation across indicators (M1–M5). The strongest performance appears in M4, approaching 80%, a pattern that aligns with earlier findings suggesting that ARCS-based learning supported by simulations and graphical activities can enhance students' analytical skills (Anto, et al., 2022). This trend reinforces the conclusion that the ARCS approach effectively strengthened the Attention and Relevance components.

The relatively consistent scores observed in M1–M3 indicate that students were able to master essential competencies (such as significant figures, dimensional analysis, and vector operations) although these skills had not yet reached optimal levels. These moderate outcomes are consistent with the work of Maiti et al., (2023), who note that while ARCS helps develop procedural skills, continuous reinforcement is needed to solidify conceptual understanding. Meanwhile, the decline observed in M5 appears to reflect the greater cognitive integration required in this final competency. Sweller, et al., (2019) point out that abstract physics concepts presented in online environments often demand extended scaffolding to maintain clarity and support learners' confidence.

The bar chart of students' learning outcomes (Figure 1) shows a clear spread across the five indicators (M1–M5). The highest achievement appears in M4, reaching nearly 80%, while M1–M3 fall within a steady mid-range, and M5 shows a noticeable drop. This pattern supports earlier findings indicating that students demonstrated stronger mastery in competencies related to analyzing motion using data, graphs, and mathematical representations. These results align with Okur & Güngör, (2025) who reported that ARCS-based instruction enriched with simulations and graphical tasks can improve learners' analytical skills by promoting more active cognitive engagement. The strong performance in M4 also suggests that the ARCS approach successfully activated the Attention and Relevance components, helping students recognize the significance of motion analysis in physics learning and in their future teaching practice

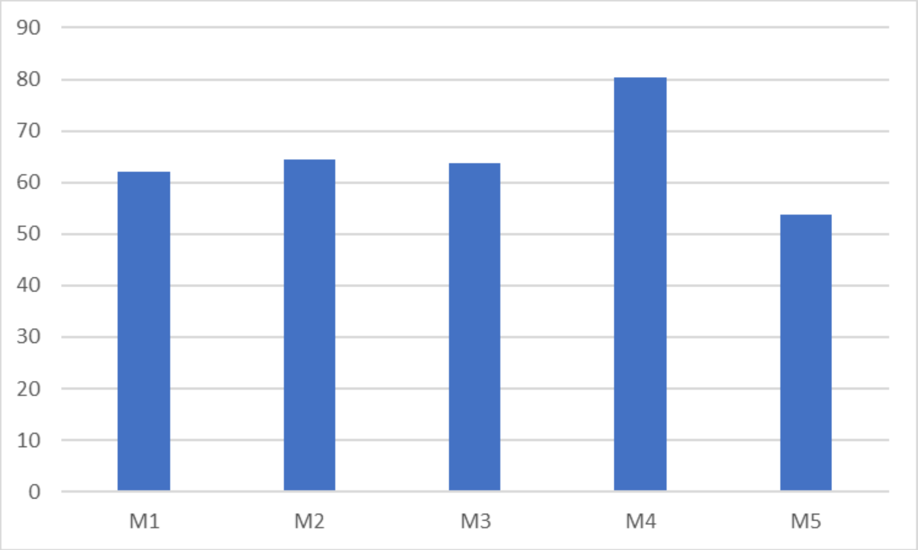

Figure 1. Percentage of Learning Outcome Achievement (M1–M5)

The diagram of motivation levels (Figure 2) also reveals clear variation across the indicators (H1–H4). The highest score appears in H3, exceeding 80%, suggesting that students felt strong intrinsic motivation and perceived the learning activities as both engaging and personally meaningful. This result corresponds to the Relevance and Attention components of the ARCS framework, which have been shown to strengthen motivational engagement when learners can clearly see the purpose and usefulness of the material (Molin & Brandt, 2023) The high score in H3 likely reflects the effective use of interactive activities, simulations, or contextualized tasks—strategies widely recognized as crucial for sustaining motivation in online learning settings.

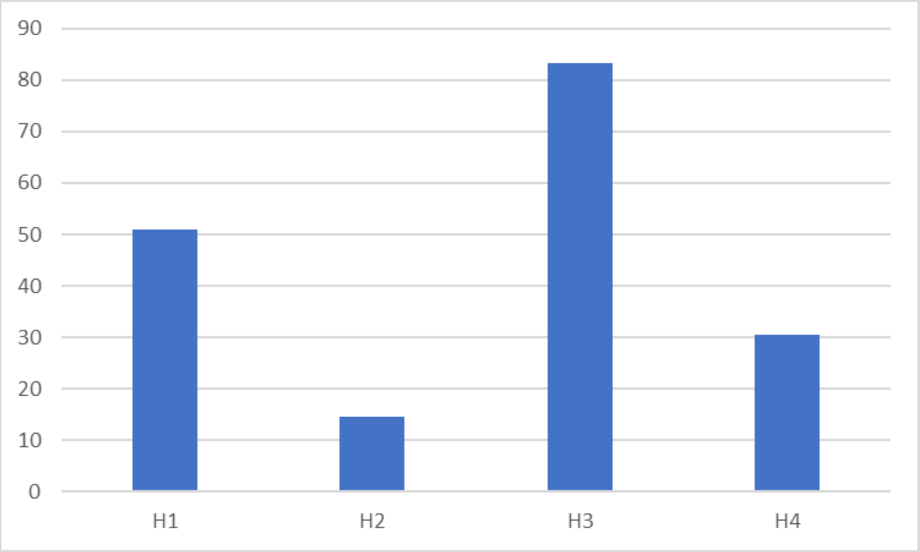

Figure 2. Percentage of Learning Motivation Indicators (H1–H4)

The diagram illustrating motivation levels (Figure 2) also shows clear variation across indicators (H1–H4). The highest score is seen in H3 (above 80%), indicating strong intrinsic motivation—consistent with the findings of Wang, (2022) and Zhao, (2021) In contrast, the notably low score in H2 (around 15%) confirms that appreciation and satisfaction were the weakest components. This pattern aligns with Ignacio, et al., (2021), who emphasize that without meaningful reinforcement, motivational persistence tends to decline. Similar trends have been reported in national studies Xiao & Sun, (2021)as well as Yu, et al., (2020), found that deficiencies in satisfaction can diminish students' persistence in learning physics.

Overall, the diagram reinforces the quantitative results by visually highlighting the areas in which the ARCS approach was most and least effective. While the components of Attention and Relevance appear to be well implemented—contributing to significant gains in both learning outcomes and motivation—the low performance in appreciation-related indicators signals the need for strengthening the Satisfaction component to support sustained learner motivation. Taken together, these findings affirm the substantial advantages of applying the ARCS model in online physics instruction, while also pointing to specific areas that should be refined in future course iterations.

3.1 The Effectiveness of ARCS on Learning Motivation

The first research question asked whether the ARCS model significantly increases student motivation in an online Basic Physics course. The results showed moderate-to-high levels of motivation across four of the five indicators, with the highest scores observed for "desire and willingness to succeed" (74.4%) and "conducive learning environment" (80.3%). These findings align with the theoretical basis of the ARCS model, which posits that systematically addressing attention, relevance, confidence, and satisfaction leads to improved learner motivation (Keller, 2010). The strong performance on the "desire to succeed" indicator specifically reflects the successful activation of the Confidence component, where students received scaffolded tasks and formative feedback that gradually built their belief in their ability to master physics concepts. The high rating for "conducive learning environment" suggests that the structured online activities, interactive simulations (e.g., PhET), and predictable weekly routines effectively supported learner autonomy and engagement—characteristics consistent with Self-Determination Theory's basic need for autonomy and relatedness (Deci & Ryan, 2000).

However, the finding that the "appreciation in learning" indicator scored only 31.9% indicates a substantial Satisfaction gap that partially qualifies the answer to the first research question. While the ARCS model successfully enhanced most motivational components, the satisfaction/reinforcement mechanism was inadequately implemented in the online setting. This low score on appreciation echoes findings from Li, Zhang and Liu (2021), who reported that without meaningful reinforcement and recognition, motivational persistence tends to decline over time. In the present study, recognition was limited to occasional verbal praise and a digital badge system that students perceived as tokenistic. From a Self-Determination Theory perspective (Deci & Ryan, 2000), this suggests that the basic psychological need for competence (feeling effective and recognized for one's achievements) was insufficiently satisfied. Unlike face-to-face settings where instructors can provide spontaneous, personalized acknowledgment, the online environment requires deliberate, structured mechanisms for recognition—such as public commendations in the learning management system, student-of-the-week awards, or opportunities for students to showcase exemplary work.

This Satisfaction gap has important implications for the first research question. Answering it more completely: the ARCS model significantly increases most dimensions of learning motivation in online physics education, except for the satisfaction/appreciation component unless reinforced with deliberate, personalized recognition strategies. Therefore, future implementations of ARCS in online settings should allocate specific instructional design attention to the Satisfaction component—for example, through gamified elements (points, badges, leaderboards) that are transparent, cumulative, and tied to meaningful achievements (Ernawati, Sari & Pratiwi, 2022).

3.3 Differential Learning Outcomes Across Sub-CPMK Competencies

The second research question asked how learning outcomes differ across cognitive sub-competencies after ARCS-based instruction. The results revealed striking variation: students performed well on Sub-CPMK 3 (motion analysis via data, graphs, and equations: 65.2%), moderately on Sub-CPMK 1 (measurement and significant figures: 35.2%) and Sub-CPMK 4 (Newton's laws: 24.8%), and extremely poorly on Sub-CPMK 2 (vector resolution and dipole moments: 14.6%). This differential pattern provides a nuanced answer: the ARCS model is highly effective for competencies that are visually representable and procedurally explicit, but largely ineffective for abstract, spatially demanding concepts without additional cognitive scaffolding.

The strong performance on Sub-CPMK 3 (motion analysis) can be explained by the alignment between the nature of the content and the ARCS strategies employed. Motion analysis lends itself well to visual representations—position-time graphs, velocity-time graphs, animated simulations of moving objects—which directly support the Attention component (capturing curiosity through dynamic visuals) and Relevance (connecting abstract graphs to real-world motion, such as car acceleration or projectile motion). Furthermore, the procedural, step-by-step nature of interpreting graphs (e.g., slope = velocity, area = displacement) matches the Confidence component's emphasis on breaking complex tasks into manageable sub-steps with immediate feedback (Keller, 2010). Huang, Lin and Cheng (2019) similarly found that ARCS-based instruction enriched with simulations and graphical tasks significantly improved learners' analytical skills in science.

In contrast, the extremely low performance on Sub-CPMK 2 (vector resolution and dipole moments: 14.6%)—the lowest score in the entire study—demands careful interpretation. Vector operations require multiple simultaneous cognitive processes: decomposing a vector into components (requiring trigonometric reasoning), mentally rotating and translating spatial representations, and integrating algebraic notation ($F_x = F \cos \theta$) with geometric diagrams. This form of representational fluency—the ability to move fluidly among graphical, algebraic, and geometric representations—is notoriously difficult for novices, especially in online environments where embodied, real-time guidance is limited (Siregar & Nasution, 2020; Riyadi, Firdaus & Putri, 2021). From a cognitive load perspective (Mayer, 2014), the simultaneous demands of these representational translations likely exceeded students' available working memory capacity, resulting in surface processing (guessing or skipping) rather than deep conceptual understanding.

Significantly, the ARCS intervention did provide PhET interactive simulations for vector addition. However, these simulations were used as demonstrations rather than as interactive practice with immediate, corrective feedback. Students submitted vector assignments asynchronously and received written feedback days later, by which time misconceptions had already solidified. This delay fundamentally undermined the Confidence component, which requires that students experience success through scaffolded, low-stakes practice before being formally assessed. As Lin, Chai and Jong (2023) argued, for highly abstract and spatially complex constructs, ARCS becomes more impactful only when paired with progressive visual supports and iterative feedback that gradually build learners' confidence. The present study's results empirically confirm that proposition.

The moderate performance on Sub-CPMK 1 (measurement and dimensional analysis: 35.2%) and Sub-CPMK 4 (Newton's laws: 24.8%)—both below the 70% KKM—indicates that while some learning occurred, mastery was not achieved. These topics are less abstract than vectors but still require multi-step reasoning (e.g., converting units, applying F = ma to multi-body systems). The moderate scores suggest that the ARCS model enhanced engagement and procedural skill development, but insufficient practice and feedback cycles prevented full conceptual consolidation. Maiti et al., (2023) noted a similar pattern: while ARCS supports the development of procedural skills for well-defined problems, sustained reinforcement and varied practice contexts are necessary for transfer to more complex, ill-structured problems.

Taken together, these findings answer the second research question by revealing a content-dependent effectiveness profile for the ARCS model in online physics education. The model works well for visually rich, procedurally explicit competencies (Sub-CPMK 3), moderately for procedural but less visual competencies (Sub-CPMK 1 and 4), and poorly for abstract, spatially demanding competencies (Sub-CPMK 2) in the absence of supplementary cognitive scaffolding.

3.4 Pedagogical Implications: Bridging Motivation and Cognition

The differential effectiveness of the ARCS model across Sub-CPMK competencies has direct implications for instructional design in online physics education. For abstract topics such as vectors, dipole moments, and field concepts, the model's four components—even when fully implemented—are necessary but not sufficient. These topics require representational scaffolding that goes beyond motivational support. Based on the present findings and cognitive load theory (Mayer, 2014; Sweller, 1988), three specific instructional strategies are recommended for future ARCS implementations when teaching abstract physics concepts online:

First, faded worked examples. Students should first study fully worked vector problems with explanatory annotations (e.g., "Step 1: Identify the angle from the horizontal. Step 2: $F_x = F \cos \theta$. Step 3: $F_y = F \sin \theta$"). Then, partially completed examples with blanks guide students to complete the missing steps. Finally, students solve problems independently. This sequence reduces cognitive load while gradually transferring responsibility to the learner, directly supporting the Confidence component (Keller, 2010).

Second, immediate corrective feedback. Unlike the delayed feedback used in this study (days later), effective vector instruction requires immediate, automated feedback that detects specific errors (e.g., "You used sine instead of cosine. Remember: adjacent/hypotenuse = cosine") and provides a micro-scaffold (e.g., "Try drawing the triangle again, labeling the angle and sides"). Learning management systems or intelligent tutoring systems can be programmed to deliver such feedback automatically, addressing the Satisfaction gap by providing timely reinforcement.

Third, progressive visualization sequences. Instruction should begin with static 2D vector diagrams with clearly labeled components, progress to animated step-by-step decomposition (showing the vector “breaking apart” into components), and then introduce 3D representations or dipole field visualizations. Each step should include self-explanation prompts (e.g., “Why is the x-component positive but the y-component negative here?”) that require students to explicitly articulate their reasoning, promoting metacognitive awareness (Flavell, 1979; Schunk, Meece & Pintrich, 2014).

These recommendations do not replace the ARCS model but rather augment it for abstract topics. The ARCS model provides the motivational why (attention, relevance, confidence, satisfaction), while cognitive scaffolding provides the procedural how (worked examples, feedback loops, progressive visualization). In online physics education, both are essential.

3.5 Study Limitations and Future Directions

Interpretation of these findings must be considered within the study’s methodological constraints. The pre-experimental one-shot case study design (treatment → post-test, without a pretest or control group) precludes causal claims about the ARCS model’s effectiveness. Without a pretest, learning gains (improvement from baseline) cannot be calculated; without a control group receiving conventional instruction, observed post-test scores cannot be attributed definitively to the ARCS intervention rather than to history, maturation, or selection biases (Campbell & Stanley, 1963). Consequently, statements about “the ARCS model enhancing motivation and learning” should be understood as post-intervention descriptive comparisons against a fixed benchmark (KKM = 70), not as causal inferences about the model’s comparative effectiveness.

Additionally, the sample (n = 37, all chemistry education majors at one Indonesian university) limits generalizability. Chemistry education students may differ systematically from physics majors or engineering students in prior physics preparation, mathematical self-efficacy, and motivational dispositions (Schunk et al., 2014). The results may also not generalize to other course formats (blended, flipped, or fully face-to-face), other cultural contexts where collectivist versus individualist motivational drivers differ (Suryadi, Putra & Wulandari, 2021), or to physics sub-disciplines with different representational demands (e.g., thermodynamics vs. electromagnetism).

Future research should employ stronger experimental designs—specifically, randomized controlled trials or at least pretest-posttest control group designs—with larger, multi-site samples that include both STEM majors and non-majors. Delayed retention tests (e.g., four to six weeks post-intervention) should be included to assess whether ARCS-induced motivational and learning gains persist over time. Additionally, future studies should conduct item-level error analysis on low-performing Sub-CPMK items (e.g., classifying student errors on vector decomposition as trigonometric, representational, or procedural) to tailor scaffolding more precisely. Finally, researchers should explore adaptive ARCS systems that dynamically adjust the emphasis on each component (e.g., increasing Satisfaction prompts when a student’s engagement flags, or intensifying Confidence scaffolding when error rates exceed a threshold) based on real-time learning analytics.

4. CONCLUSION

This study aimed to answer two research questions: (1) To what extent does the ARCS model increase student motivation in an online Basic Physics course? and (2) How do learning outcomes differ across cognitive sub-competencies after ARCS-based instruction? The findings provide partial affirmative answers. Regarding motivation, the ARCS model successfully enhanced most motivational components—particularly desire to succeed (74.4%) and perceived conducive learning environment (80.3%)—but failed to adequately address the Satisfaction component, as evidenced by the very low score for appreciation in learning (31.9%). Thus, the model is effective for attention, relevance, and confidence, yet requires deliberate reinforcement strategies to fulfill the satisfaction component in online settings. Regarding learning outcomes, the ARCS model produced highly variable results across sub-competencies: strong performance in motion analysis (Sub-CPMK 3: 65.2%), moderate to low in measurement and Newton's laws (Sub-CPMK 1: 35.2%; Sub-CPMK 4: 24.8%), and extremely low in vector and dipole moment concepts (Sub-CPMK 2: 14.6%). This differential pattern demonstrates that ARCS is highly effective for visually representable, procedurally explicit content but largely ineffective for abstract, spatially demanding topics without additional cognitive scaffolding.

In terms of contextual contributions, this research provides empirical evidence from an under-researched higher education physics context in Indonesia, introduces a novel Sub-CPMK-level analysis that reveals competence-specific effectiveness, and identifies the Satisfaction gap as a critical weakness in online ARCS implementations while empirically demonstrating that abstract concepts require supplementary representational scaffolding beyond motivational design. However, the findings must be interpreted within the study's methodological constraints: the pre-experimental one-shot case study design (X → O) lacked a pretest and control group, precluding causal claims about the ARCS model's effectiveness, as observed post-intervention outcomes may be influenced by history, maturation, or selection biases rather than solely by the intervention. The absence of a pretest prevents calculation of learning gains, and the lack of a comparison group precludes any conclusion about ARCS's superiority over conventional instruction or alternative motivational models. Additionally, the single-cohort sample (n = 37, chemistry education majors at one university) limits generalizability to other populations, disciplines, or cultural contexts. Therefore, this study provides preliminary feasibility evidence and descriptive benchmarking against a fixed competency standard (KKM = 70), not confirmatory causal evidence.

Consequently, future research should employ stronger designs, such as randomized controlled trials or pretest-posttest control group designs, with larger, multi-site samples and delayed retention measures to validate these effects. For practical application, instructors implementing ARCS in online physics courses should deliberately strengthen the Satisfaction component through personalized recognition, gamified badges, and timely feedback. Furthermore, they should augment the model with cognitive scaffolds—such as faded worked examples, immediate corrective feedback, and progressive visualization sequences—when teaching abstract, spatially demanding topics like vectors and dipole moments to bridge the gap between motivation and conceptual mastery.

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