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Strengthening Cultural Care Attitudes through Ethnoscience-Based Physics Learning: A Quasi-Experimental Study with Pre-Service Teachers

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ABSTRACT
This study examined differences in the improvement of cultural care attitudes among pre-service physics teachers who participated in three instructional conditions within ethnoscience-based physics education. The study employed a quasi-experimental pretest-posttest design involving 270 participants from three teacher education institutions in Yogyakarta, Indonesia, who were distributed across one experimental group and two control groups. The experimental group received physics instruction that positioned ethnoscience and local cultural resources as central learning contexts, whereas the two control groups experienced alternative instructional conditions with less explicit integration of local cultural resources. Cultural care attitudes were measured using an instrument developed and validated in a previous study. Data were analysed using descriptive statistics, paired-samples t tests, ANCOVA with pretest as a covariate, one-way ANOVA on gain scores, and additional cross-campus analyses. The findings showed that all groups improved significantly from pretest to posttest, but the experimental group demonstrated the strongest improvement and the highest adjusted posttest mean after baseline differences were controlled. Pairwise comparisons confirmed that the experimental group outperformed both control groups, while the group by campus interaction was not significant. These findings suggest that different instructional conditions were associated with different affective outcomes and that ethnoscience-based physics learning appeared to support culturally oriented dispositions among pre-service physics teachers.

INTRODUCTION

Physics education in higher education is often organised around concepts, formulas, and procedures, while the relationship between scientific knowledge and students' sociocultural worlds remains underdeveloped. This separation may allow students to achieve cognitive mastery, but it does not necessarily help them see local knowledge, cultural practices, and community experiences as meaningful resources for learning science. In contexts where learners live within rich cultural environments, physics instruction that remains detached from culture risks presenting science as abstract, neutral, and distant from everyday life. Ethnoscience-based learning responds to this problem by positioning science not only as a body of concepts, but also as a space for dialogue with the cultural realities in which learners participate (Festiyed et al., 2026; Hikmah et al., 2025; Rahmawati et al., 2020).

Studies on ethnoscience and local wisdom in science education have shown positive effects on scientific literacy (Stabita et al., 2025) , learning outcomes, higher-order thinking skills, engagement, cultural identity, cultural awareness, conservation values, and attitudes toward science (Akmar et al., 2026; Ali et al., 2025; Rasmawan et al., 2025; Sihombing et al., 2025; Blackie, 2024; El-Hani & Ludwig, 2024; Yazidi & Rijal, 2024; Michie et al., 2023; Gao et al., 2020; Syahrial et al., 2019; Zidny et al., 2020). These findings indicate that locally grounded learning can influence not only what students understand, but also how they relate science to culture and social life. This direction is consistent with culturally responsive science pedagogy, which treats students' experiences, community knowledge, and ways of life as pedagogical assets rather than decorative additions to instruction (Smith et al., 2022; Marosi et al., 2021; Brown, 2017). Therefore, affective outcomes should not be treated as secondary by-products of science learning, but as central indicators of whether instruction successfully builds meaningful relations between scientific concepts and learners' cultural worlds.

This issue is especially important in teacher education. Pre-service physics teachers are not prepared only to master disciplinary content, but also to teach learners from diverse sociocultural backgrounds. Cultural readiness, intercultural competence, and sensitivity to diversity are increasingly recognised as integral dimensions of teaching professionalism (Gulya & Fehérvári, 2023; Romijn et al., 202; Cherng & Davis, 2019). Future teachers with stronger cultural orientations are more likely to build inclusive learning environments, respond to students' lived experiences, and connect science instruction to real-life contexts (Hu et al., 2021; Moore et al., 2021). For this reason, cultural care attitudes need to be examined as substantive learning outcomes in physics teacher education.

In this article, cultural care attitudes refer to affective orientations that lead students to give attention, appreciation, and serious consideration to cultural values, practices, and meanings in physics learning. This construct is narrower than cultural competence or intercultural performance because it does not focus primarily on effective functioning in intercultural interaction. Rather, it emphasises students' disposition to regard culture as a pedagogical and epistemic resource in understanding phenomena, constructing meaning, and connecting scientific knowledge with social life. This emphasis overlaps with work on cultural humility, cultural empathy, and readiness for culturally responsive teaching, but remains specific to the context of science learning (Zhang & Noels, 2023; Foronda, 2020; Lekas et al., 2020).

Despite growing evidence on the benefits of ethnoscience-based science learning, there remains a specific gap in quasi-experimental research that directly compares changes in cultural care attitudes across multiple instructional groups and multiple campus contexts. Existing studies have generally shown that ethnoscience, local wisdom, and culturally responsive pedagogy can support cognitive, affective, and cultural outcomes, including engagement and cultural awareness, but fewer studies have tested whether cultural care attitudes change differently when pre-service physics teachers experience clearly differentiated instructional conditions. Unlike broader affective constructs such as engagement, cultural awareness, or attitudes toward science, cultural care attitudes focus more specifically on students' disposition to treat cultural values, local practices, and community knowledge as pedagogical and epistemic resources in physics learning. This gap is important because improvement in affective scores may simply reflect general instructional exposure unless it is examined through comparative designs that include an experimental group, comparison groups, baseline control, and cross-context analysis. Therefore, the novelty of this article lies in moving beyond instrument validation and general claims about ethnoscience by providing quasi-experimental evidence on how cultural care attitudes develop differently across three instructional conditions and three higher education institutions.

On this basis, the present study examines differences in cultural care attitude changes among pre-service physics teachers who experienced three instructional conditions. Specifically, it analyses pretest-posttest changes within each group, compares the magnitude of change across groups, tests whether group differences remain after controlling for initial scores, and explores whether similar patterns emerge across three campus contexts. Through this design, the article shifts the discussion of ethnoscience-based physics learning from whether culture can be incorporated into instruction toward how different instructional conditions shape the cultural orientations of future physics teachers.

METHOD

Research Design

This study employed a quasi-experimental design with a pretest-posttest structure across three instructional groups. The design was selected because the main objective was not merely to describe score changes, but to compare changes in affective outcomes across different instructional conditions. The groups were organised using existing class-based instructional settings rather than individual random assignment, which is consistent with the practical constraints of higher education classroom research. By involving one experimental group and two control groups, the study was able to capture two kinds of evidence simultaneously: score changes within each group and differences in outcomes across groups after the instructional process.

The use of a quasi-experimental design was also appropriate for the context of higher education research, where full random assignment is not always feasible in practice. Under such conditions, between-group comparisons remain possible as long as the interpretation of results takes participants' initial conditions into account. For this reason, the study did not rely solely on raw gain analysis, but also used an analytical approach that controlled for baseline scores when comparing final outcomes.

Substantively, a three-group design offered an additional advantage. Differences in outcomes could be interpreted not simply as a contrast between an experimental group and a single control group, but as a richer comparative pattern across three instructional conditions. This made it possible to read the findings more cautiously and to avoid overdependence on a single comparison line.

Participants and Research Context

The participants were 270 pre-service physics teachers drawn from three higher education institutions in the Special Region of Yogyakarta, namely UIN Sunan Kalijaga, Yogyakarta State University, and Sarjanawiyata Tamansiswa University. Participants were selected from intact classes that were available for instructional intervention in the relevant science or physics education courses. Because the study used a quasi-experimental design, students were not randomly assigned at the individual level. Instead, class-based groups were designated as the experimental group, control group 1, and control group 2, while maintaining a balanced distribution across the three institutions. The final sample consisted of 90 students in the experimental group, 90 students in control group 1, and 90 students in control group 2. Within each group, campus composition was also balanced, with 30 students from each institution.

The inclusion of three campuses was not intended to support broad claims of generalisation, but rather to ensure that the interpretation of results did not rest on a single institutional context. By involving more than one institution, the study could examine whether the pattern of between-group differences moved in the same general direction across different academic settings. Accordingly, campus in this study is better understood as a contextual source of analytical enrichment than as the primary variable of interest. This sampling and grouping procedure also means that potential selection bias could not be fully eliminated. To reduce this limitation analytically, the study measured baseline cultural care attitudes through a pretest and used ANCOVA to compare posttest outcomes while controlling for initial scores.

Academically, all participants were enrolled in physics education programmes or were being prepared as future physics teachers, making them directly relevant to the study's focus on ethnoscience-based physics learning. This disciplinary consistency was important because it maintained alignment among the instructional design, the instrument employed, and the outcome domain being measured. Thus, the observed affective outcomes were interpreted specifically within the context of pre-service physics teacher education rather than in relation to university students in general.

Instrument

The main outcome of this study was cultural care attitudes, measured using the final version of a cultural care attitude instrument that had been developed and validated in a previous study within the context of ethnoscience-based physics education. Although the present article did not aim to revalidate the instrument, essential psychometric information is reported here to clarify the quality of the measure used in the quasi-experimental analysis.

The initial version of the instrument consisted of 32 items. After expert review, item revision, and confirmatory factor analysis, the final version used in this study retained 22 valid items. The instrument used a four-point Likert scale ranging from 1 to 4, with higher scores indicating stronger cultural care attitudes. Some negatively worded items were reverse-scored before total scores were calculated. The final score analysed in this study was the total cultural care attitude score obtained from the sum of all retained items.

The instrument measured four dimensions of cultural care attitudes: awareness, openness, knowledge, and empathy. Awareness refers to students' interest in culture, recognition of cultural similarities and differences, and understanding of the role of culture in learning. Openness refers to students' acceptance of cultural differences and willingness to interact with people from different cultural backgrounds. Knowledge refers to students' understanding of cultural diversity and their ability to identify differences as a basis for understanding other cultures. Empathy refers to students' affective sensitivity toward the cultural backgrounds of others and their willingness to engage with culturally different communities.

Content validity was examined through expert judgement using Aiken's V. The validation process indicated strong content validity, with item-level Aiken's V values ranging from 0.917 to 1.000. Construct validity was examined using first-order confirmatory factor analysis. The CFA process began with 32 items and retained 22 items with standardized factor loadings above 0.50, while 10 items with insufficient loadings were removed. The retained items represented the four intended dimensions proportionally: awareness, openness, knowledge, and empathy. The internal consistency of the final instrument was strong, with Cronbach's Alpha = 0.881.

In the present study, the instrument was treated as an outcome measure rather than as an object of further scale development. Using the same validated instrument across all groups allowed outcome comparisons to be made within a consistent measurement framework. As a result, differences in pretest, posttest, and gain scores were interpreted as differences in instructional outcomes rather than as consequences of measurement variation.

Instructional Procedure and Data Collection

The instructional intervention was implemented over five meetings, with each meeting lasting one instructional hour of 50 minutes. The same pretest-posttest structure was applied across the three groups. The pretest was administered before the instructional intervention began, while the posttest was administered after the fifth meeting had been completed. This procedure ensured that changes in cultural care attitudes could be compared across groups within the same measurement sequence.

The learning content was organised around physics and integrated science concepts that could be connected to the local cultural context of the Panji Bobung mask from Gunung Kidul, Yogyakarta. The topics included force and motion, material properties, changes in the state of matter, energy transformation, wood characteristics, and natural colouring processes. These topics were selected because they could be linked to the production of the Panji Bobung mask, including the selection and treatment of wood, the carving process, the use of tools, and the application of natural dyes. Thus, the cultural context was not used merely as an illustration, but as a learning context through which students could examine the relationship between physics concepts, local artefacts, and community knowledge.

The experimental group received the Inquiry ETNIK-STEAM learning model. This model integrated inquiry, ethnoscience, and STEAM through six learning phases: introduction of ethnoscience-based problems, formulation of ethnoscience-based questions, exploration of scientific literature and local narratives, formulation of hypotheses from a STEAM perspective, implementation of ethnoscience projects or experiments and data analysis, and presentation of findings followed by scientific and cultural reflection. During these phases, students observed cultural phenomena related to the Panji Bobung mask, discussed local narratives, formulated investigable questions, designed small projects or experiments, analysed data, and reflected on the scientific and cultural meanings of their findings.

Control group 1 received problem-based learning. In this group, students were also encouraged to analyse problems and communicate solutions, but the learning process was not structured through the full Inquiry ETNIK-STEAM syntax and did not position the Panji Bobung cultural context as the central organising framework of instruction. Control group 2 received conventional inquiry instruction. Students in this group followed inquiry-oriented activities such as questioning, exploring, and drawing conclusions, but without explicit integration of ethnoscience, STEAM-based project work, or systematic reflection on local cultural meanings. Therefore, the main distinction among the three groups lay in the degree of integration among inquiry activities, local cultural resources, STEAM-oriented projects, and cultural reflection. The instructional differences among the three groups are summarized in Table 1.

Table 1. Instructional Differences Among The Three Groups

Aspect	Experimental group	Control group 1	Control group 2
Instructional model	Inquiry ETNIK-STEAM	Problem-based learning	Conventional inquiry
Duration	Five meetings, 50 minutes each	Five meetings, 50 minutes each	Five meetings, 50 minutes each
Cultural context	Panji Bobung mask as the central ethnoscience context	Cultural context not used as the central instructional structure	Cultural context not explicitly integrated
Main learning orientation	Inquiry, ethnoscience, STEAM project, and cultural reflection	Problem analysis and solution development	Inquiry process without systematic ethnoscience integration
Learning materials	Force and motion, material properties, changes in matter, energy transformation, wood characteristics, and natural colouring processes connected to mask production	Comparable science/physics learning content through problem-based activities	Comparable science/physics learning content through conventional inquiry
Student activities	Observing cultural phenomena, formulating ethnoscience problems, exploring literature and local narratives, designing hypotheses, conducting projects or experiments, analysing data, presenting findings, and reflecting on	Analysing problems, discussing possible solutions, and communicating group findings	Asking questions, exploring information, drawing conclusions, and reporting learning outcomes

Aspect	Experimental group	Control group 1	Control group 2
	scientific-cultural meanings		
Distinctive feature	Explicit integration of local culture as a pedagogical and epistemic resource	Focus on problem-solving, without full ethnoscience-STEAM integration	Focus on inquiry steps, without explicit cultural and STEAM project integration

Data collection was conducted in two main stages. The pretest was used to identify students' initial cultural care attitude scores before they experienced the instructional condition assigned to their group. The posttest was used to capture students' cultural care attitude scores after the intervention. The difference between posttest and pretest scores was then calculated as the gain score, which provided an initial indication of the magnitude of change within each group before further inferential analyses were conducted.

This procedure allowed the study to generate two forms of evidence. First, it showed whether cultural care attitudes changed within each group after instruction. Second, it enabled comparison of whether different instructional conditions were associated with different patterns of affective change. In this way, data collection was aligned with the comparative purpose of the study and with the need to distinguish the effect of the experimental condition from general instructional exposure.

Data Analysis

The analysis began with descriptive statistics to summarise participant distribution, pretest scores, posttest scores, and gain scores for each group. This stage was important for displaying the basic pattern of change before moving to inferential analysis. Through descriptive statistics, the study could identify whether all groups improved, which group showed the highest gain, and how the pattern of change appeared at the campus level.

Before inferential analyses were conducted, relevant statistical assumptions were examined. Normality was assessed for pretest-posttest difference scores and gain scores using normality tests and inspection of distributional patterns. Homogeneity of variance across groups was examined using Levene's test. Linearity between the covariate and dependent variable was checked before ANCOVA by examining the relationship between pretest and posttest scores. The homogeneity of regression slopes assumption was tested by examining the interaction between pretest and group. Independence of observations was addressed through the class-based grouping procedure, in which each participant contributed only one set of pretest and posttest scores and was included in only one instructional group.

To test score changes within each group, paired-samples t tests were conducted between pretest and posttest scores after the normality of the difference scores had been considered. This analysis was used to determine whether the score changes observed descriptively were statistically significant. In addition, within-group effect sizes were calculated so that the meaning of change could be interpreted not only through significance values but also through the strength of the effect.

Between-group comparisons were conducted using ANCOVA, with posttest scores as the dependent variable and pretest scores as the covariate. This approach was selected because the baseline means across groups were not fully identical, making posttest comparisons without controlling for pretest methodologically weaker. Before conducting ANCOVA, the assumptions of linearity, homogeneity of regression slopes, homogeneity of variance, and independence of observations were examined to ensure that the model could be interpreted appropriately.

As a supporting analysis, the study also employed one-way ANOVA on gain scores, followed by Tukey post hoc tests to examine the direction of gain differences across groups. The normality of gain scores and the homogeneity of variance across groups were checked before interpreting the ANOVA results. This analysis was not positioned as the main source of evidence, but rather as reinforcement for the pattern identified through ANCOVA. In addition, supplementary campus-level analyses and a group by campus interaction test were conducted to assess whether the pattern of between-group differences remained stable across the three institutional contexts involved in the study.

Overall, the analytical strategy was designed to integrate three needs simultaneously: showing within-group change, comparing between-group outcomes more rigorously, and examining the consistency of the pattern across different campus contexts. In this way, the interpretation of findings did not rest on a single type of statistic, but was built from several layers of mutually reinforcing evidence.

RESULTS AND DISCUSSION

Results

Participant Distribution and Baseline Conditions Across Groups

The analysis included 270 pre-service physics teachers who were evenly distributed across three instructional groups. The experimental group consisted of 90 students, as did control group 1 and control group 2. Within each group, campus distribution was also identical, with 30 students from UIN Sunan Kalijaga, 30 from UNY, and 30 from UST. This composition provided a reasonably strong comparative basis because the three groups were formed with equal size both in terms of total participants and institutional origin.

Although participant distribution was balanced, baseline conditions across groups were not entirely identical. The experimental group had a mean pretest score of 70.31, control group 1 had 64.92, and control group 2 had 70.02. This pattern indicates that control group 1 began instruction with a lower level of cultural care attitudes than the other two groups. This difference is important because it suggests that the interpretation of final outcomes should not rest solely on raw gain scores, but needs to be confirmed through analyses that control for baseline scores.

Descriptive Changes in Cultural Care Attitude Scores

At the descriptive level, all groups showed improvement after instruction. The experimental group increased from a mean of 70.31 to 79.57, control group 1 from 64.92 to 71.21, and control group 2 from 70.02 to 74.93. In terms of mean gain, the experimental group recorded the largest increase at 9.26, followed by control group 1 at 6.29 and control group 2 at 4.91. The descriptive statistics for pretest, posttest, and gain scores across the three groups are presented in Table 2. This arrangement reveals a fairly clear hierarchy of change associated with the three instructional conditions.

Table 2. Descriptive Statistics for Pretest, Posttest, and Gain by Instructional Group

Group	n	Mean pretest	SD pretest	Mean posttest	SD posttest	Mean gain	SD gain
Experimental	90	70.311	7.067	79.567	6.959	9.256	2.429
Control 1	90	64.922	8.124	71.211	7.869	6.289	2.250
Control 2	90	70.022	8.006	74.933	7.689	4.911	1.906

This pattern suggests that instruction in all groups was associated with positive change in cultural care attitudes. However, the intensity of change was not the same. The experimental group not only improved, but improved more strongly than the two comparison groups. In other words, the descriptive evidence already points to one major finding that all groups moved in a positive direction, but the experimental group moved the farthest.

The visualisation of score changes strengthens this descriptive reading. In all three groups, the line from pretest to posttest moves upward. However, the slope of the line is steepest for the experimental group, whereas control group 1 and control group 2 show more gradual increases. These trends are illustrated in Figure 1.

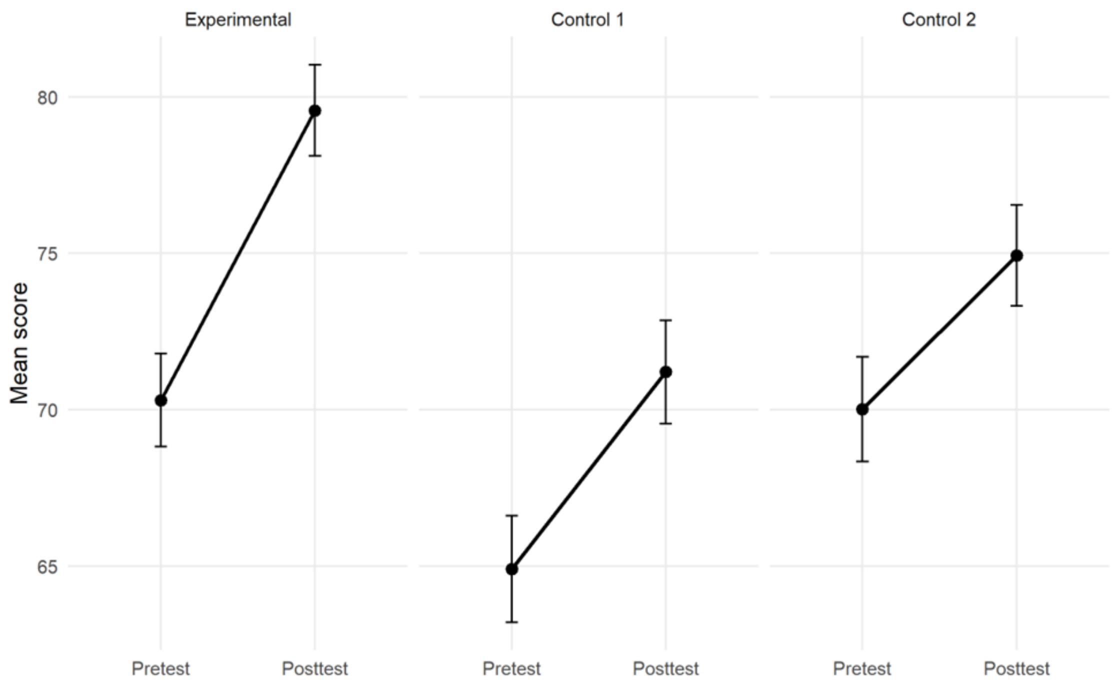

Fig. 1. Mean pretest and posttest scores by instructional group

Figure 1 highlights the trajectory of score changes from pretest to posttest across the three groups. Although all groups demonstrated positive changes, the magnitude of improvement differed. To facilitate comparison of the extent of improvement, mean gain scores were examined separately. The distribution of mean gain scores across groups is presented in Figure 2.

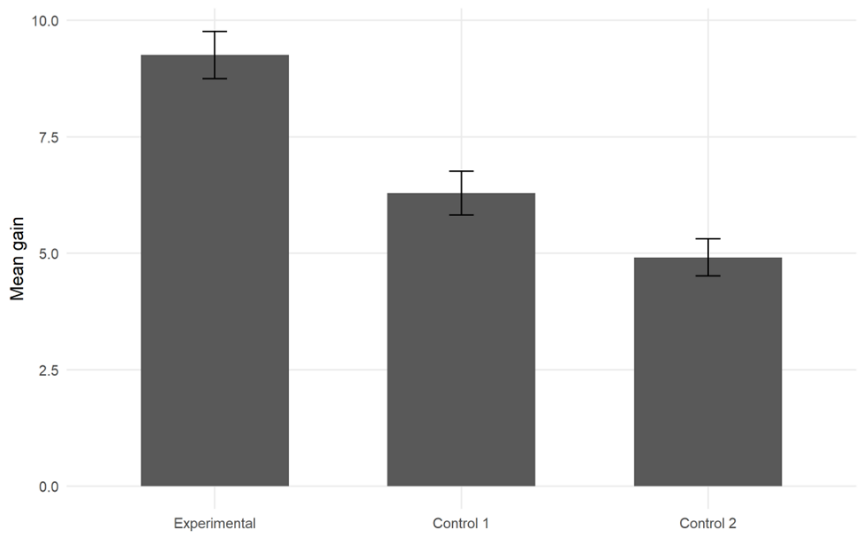

Fig. 2. Mean gain scores by instructional group

As shown in Figure 2, the experimental group achieved the highest mean gain, followed by control group 1 and control group 2. The consistency between the descriptive statistics, the trends in Figure 1, and the gain pattern in Figure 2 reinforces the interpretation that the differences among instructional conditions represent stable and meaningful patterns rather than small variations around the mean.

Within-Group Changes and Assumption Checks

Before the paired-samples t tests were interpreted, the normality of the pretest-posttest difference scores was examined. The assumption checks did not indicate serious violations that would prevent the use of parametric within-group tests. Within-group tests showed that the increase in scores across all groups was statistically significant. In the experimental group, the difference between pretest and posttest was significant, with $t = 36.148$, $p < 0.001$, and Cohen's dz = 3.810. In control group 1, the increase was also significant, with $t = 26.518$, $p < 0.001$, and Cohen's dz = 2.795. In control group 2, the rise in scores likewise remained significant, with $t = 24.446$, $p < 0.001$, and Cohen's dz = 2.577.

These findings indicate that instruction, under all three conditions, was associated with stronger cultural care attitudes. No group showed stagnation or decline. However, the main finding is not merely that all groups improved, but that the experimental group showed the strongest intensity of improvement. The mean gain of the experimental group, 9.256, exceeded that of control group 1, 6.289, and control group 2, 4.911. Within-group effect sizes followed the same direction, with the highest Cohen's dz value found in the experimental group.

Between-Group Differences After Controlling for Baseline Scores

Before comparing final outcomes across groups, the main assumptions for ANCOVA were examined. The relationship between pretest and posttest scores was inspected to ensure linearity between the covariate and dependent variable. Homogeneity of variance and independence of observations were also considered before model interpretation. In addition, the assumption of homogeneity of regression slopes was tested statistically. The interaction between pretest and group was not significant, with $p = 0.986$. This result indicates that the relationship between baseline scores and final scores was relatively comparable across the three groups. Therefore, the use of ANCOVA to compare posttest scores while controlling for pretest can be justified methodologically. The ANCOVA results for posttest scores with pretest as a covariate are presented in Table 3.

Table 3. ANCOVA Results for Posttest Scores with Pretest as a Covariate

Term	df	Sum sq	Mean sq	F	p	Partial eta squared
Pretest	1	16088.158	16088.158	3505.958	< 0.001	0.929
Group	2	928.050	464.025	101.121	< 0.001	0.432
Residual	266	1220.622	4.589			

The main evidence appears in the ANCOVA results (Table 3). After baseline scores were controlled, the effect of group on posttest scores remained significant, with $F = 101.121$, $p < 0.001$, and a partial eta squared of 0.432. This effect size indicates that differences in instructional conditions were substantively associated with variation in final cultural care attitude scores. The claim that can be drawn from this result is fairly strong: the between-group differences in final outcomes did not merely echo initial differences, but remained after baseline conditions had been taken into account.

The adjusted posttest means clarify the direction of these differences. The experimental group reached an adjusted mean of 77.806, higher than control group 1 at 74.463 and control group 2 at 73.442. Thus, the superiority of the experimental group was not merely a matter of raw gain patterns, but also of a higher final outcome after the influence of baseline scores was controlled.

Pairwise Comparisons of Adjusted Posttest Means

Pairwise comparisons showed that all between-group differences were significant (see Table 4). The experimental group scored 3.343 points higher than control group 1 and 4.365 points higher than control group 2, both at $p < 0.001$. Control group 1 also scored 1.021 points higher than control group 2, with $p = 0.007$. These results confirm that the ordering of the experimental group in the highest position, control group 1 in the middle, and control group 2 in the lowest position has a strong statistical basis. Table 4 presents the pairwise comparisons among the three groups based on adjusted posttest means.

Table 4. Pairwise Comparisons of Adjusted Posttest Means

Contrast	Estimate	SE	df	t ratio	p
Experimental – Control 1	3.343	0.332	266	10.067	< 0.001
Experimental – Control 2	4.365	0.319	266	13.666	< 0.001
Control 1 – Control 2	1.021	0.331	266	3.088	0.007

The pattern of adjusted posttest means across the three groups is further illustrated in Figure 3.

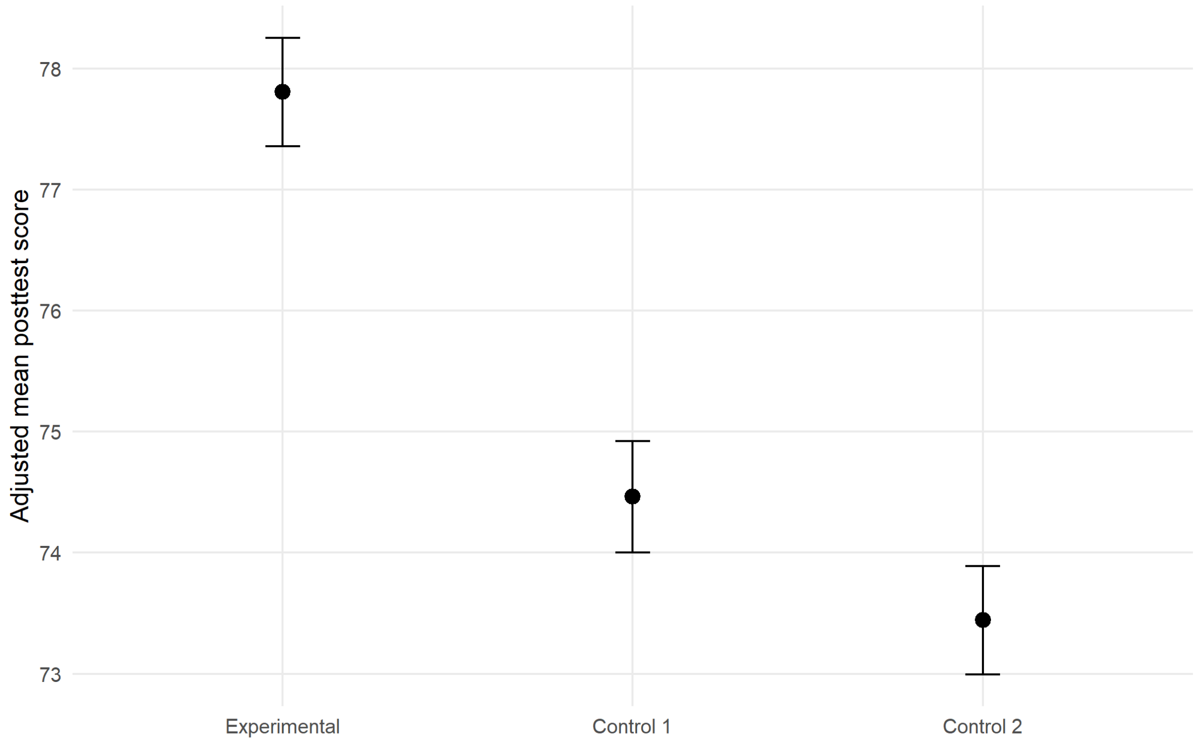

Fig. 3. Adjusted posttest means by instructional group after controlling for pretest

As shown in Figure 3, the experimental group maintained the highest adjusted posttest mean, followed by control group 1 and control group 2. The separation between confidence intervals was consistent with the pairwise comparison results, reinforcing the conclusion that the experimental treatment produced superior cultural care attitude outcomes even after baseline differences were statistically controlled.

Supporting Analysis and Cross-Campus Patterns

Gain analysis was used as supporting evidence rather than as the primary basis of inference because baseline scores across groups were not fully identical. Before the ANOVA on gain scores was interpreted, the assumptions of normality and homogeneity of variance were examined and did not show serious violations. The one-way ANOVA on gain scores still showed a significant difference, with $F = 91.187$, $p < 0.001$, and a partial eta squared of 0.406. Tukey post hoc tests indicated that the mean gain of the experimental group was significantly higher than that of both control groups, while control group 1 also exceeded control group 2. These findings reinforce the ANCOVA results in the same direction, but they are treated as supporting evidence rather than as the main inferential basis.

At the campus level, the direction of change remained similar. At UIN Sunan Kalijaga, UNY, and UST, the experimental group consistently showed higher gain scores than the two control groups, although the magnitude was not entirely identical. The cross-campus pattern indicates that the advantage of the experimental group was not confined to a single campus. However, it is important to distinguish between consistency in direction and uniformity in effect size. The direction of the experimental group's superiority remained the same across the three campuses, but the magnitude of gain still fluctuated. Descriptive statistics for each instructional group across the three campuses are summarized in Table 5.

Table 5. Descriptive summary by instructional group and campus

Group	Campus	n	Mean pretest	Mean posttest	Mean gain	SD gain
Experimental	UIN Sunan Kalijaga	30	71.200	79.967	8.767	2.473
Experimental	UNY	30	73.167	82.200	9.033	1.810
Experimental	UST	30	66.567	76.533	9.967	2.810
Control 1	UIN Sunan Kalijaga	30	59.533	66.600	7.067	1.856
Control 1	UNY	30	68.967	75.000	6.033	2.684
Control 1	UST	30	66.267	72.033	5.767	1.977
Control 2	UIN Sunan Kalijaga	30	67.300	72.633	5.333	1.422
Control 2	UNY	30	72.667	77.233	4.567	2.373
Control 2	UST	30	70.100	74.933	4.833	1.783

The interaction test results showed that the between-group differences did not change significantly by campus, with $F = 1.412$ and $p = 0.230$. In other words, campus did not shift the main pattern that had already emerged in the previous analyses. Figure 4 provides a visual comparison of pretest and posttest score trajectories across instructional groups and campuses.

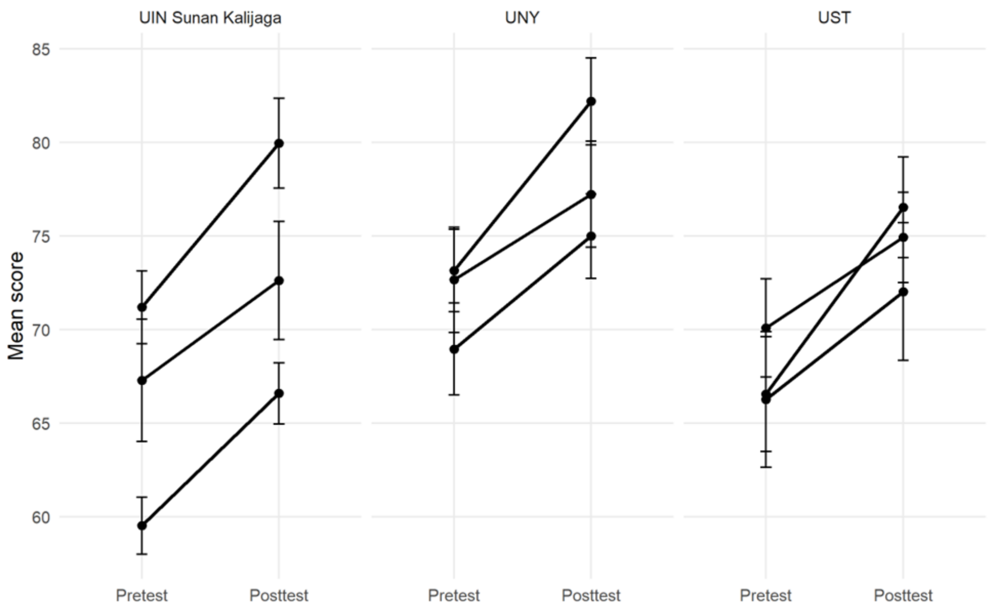

Fig. 4. Pretest-posttest patterns by instructional group across campuses

Discussion

The findings show that cultural care attitudes improved in all instructional groups, but the experimental group demonstrated the strongest improvement. This pattern indicates that affective change should not be interpreted simply as the result of students being exposed to instruction. Rather, the quality and structure of the instructional experience appear to matter. The experimental condition differed from the two control conditions because it did not merely use culture as an example or supplementary context. It organised learning around the Panji Bobung mask as a cultural artefact through which students could connect physics concepts, local knowledge, material practices, artistic processes, and community meanings. This stronger integration may explain why students in the experimental group developed a more pronounced disposition to value culture as part of science learning.

The superiority of the experimental group is theoretically plausible because the Inquiry ETNIK-STEAM model combined several mutually reinforcing components. First, the ethnoscience component made local culture visible as a legitimate source of knowledge rather than as an ornamental addition to physics instruction. Second, the inquiry component required students to formulate questions, investigate phenomena, and interpret evidence, which may have encouraged a more active and reflective relationship with cultural materials. Third, the STEAM-oriented project work allowed students to move beyond verbal discussion toward concrete engagement with artefacts, materials, design, and representation. Fourth, the reflection phase explicitly asked students to interpret their findings from both scientific and cultural perspectives. Among these components, the explicit cultural reflection and the positioning of the Panji Bobung mask as a central epistemic resource were likely the most influential for cultural care attitudes because they directly targeted students' awareness, openness, knowledge, and empathy toward culture.

These findings strengthen previous studies showing that ethnoscience-based learning and local wisdom can support engagement, cultural awareness, conservation values, and positive attitudes toward science (Akmar et al., 2026; Festiyed et al., 2026; Ali et al., 2025; Rahmawati et al., 2020). However, the distinctive contribution of this study lies not merely in the larger sample size, but in the specific affective construct and comparative evidence it offers. Earlier studies, such as Rahmawati et al. (2020), have shown that ethnopedagogy can improve student engagement and cultural awareness. The present study extends this line of work by focusing on cultural care attitudes, namely students' disposition to treat cultural values, local practices, and community knowledge as pedagogical and epistemic resources in physics learning. This construct is more specific than general cultural awareness because it concerns not only recognising culture, but also valuing culture as something that should be seriously considered in understanding and teaching physics.

At the same time, the improvement in the control groups should not be dismissed. Control group 1, which received problem-based learning, and control group 2, which received conventional inquiry instruction, also showed significant gains. This result is reasonable because both approaches still involve active learning elements. Problem-based learning can encourage students to analyse contextual problems, discuss alternative solutions, and communicate group findings, while inquiry instruction can promote questioning, exploration, and conclusion-making. These processes may indirectly strengthen students' openness and awareness, even when local culture is not systematically positioned as the central learning framework. Therefore, the difference between the experimental and control groups should not be read as a contrast between effective and ineffective instruction, but as evidence that the degree of cultural integration and reflective engagement shapes the strength of affective change.

The baseline-controlled analysis adds an important layer to this interpretation. Since the groups did not begin from exactly the same pretest level, simple gain comparisons could have been misleading. The use of ANCOVA helped reduce this risk by comparing posttest outcomes after initial scores were controlled. The finding that the experimental group remained superior after this control suggests that its advantage was not merely a consequence of starting position. Nevertheless, the strong role of the pretest also reminds us that initial dispositions matter. Students who already possess higher cultural care attitudes may respond differently to culturally oriented instruction than students whose initial orientation is lower. This means that future studies should not only compare group averages, but also examine whether students with different baseline profiles benefit differently from ethnoscience-based learning.

Several alternative explanations also need to be considered critically. One possibility is a teacher effect. If different lecturers implemented the three instructional conditions, variations in teaching style, facilitation skill, enthusiasm, or familiarity with local culture may have contributed to the differences observed. Another possibility is a campus effect, since institutional culture, student background, and prior exposure to local wisdom may differ across UIN Sunan Kalijaga, UNY, and UST. The non-significant group by campus interaction suggests that the main pattern was relatively stable across institutions, but it does not completely eliminate the possibility of contextual influence. It only indicates that campus did not significantly alter the direction of the group differences in this dataset. A further possibility is a pretest sensitisation effect, because completing the cultural care attitude instrument before instruction may have made students more aware of cultural issues during subsequent learning. Since all groups completed the same pretest, this effect would not fully explain the experimental group's stronger performance, but it may help explain why all groups improved.

From a theoretical perspective, the findings support the argument that culturally responsive science pedagogy becomes more powerful when culture is treated as a source of meaning, not merely as a context for examples. Within culturally responsive pedagogy, students' experiences, values, and sociocultural contexts are recognised as legitimate learning resources (Smith et al., 2022; Marosi et al., 2021). The present study suggests that this recognition may be especially consequential when it is embedded in inquiry and project-based activity. Students do not only hear that culture matters; they investigate, discuss, model, design, and reflect on cultural artefacts in relation to scientific concepts. This movement from recognition to active epistemic engagement may be the mechanism that distinguishes cultural care attitudes from more general cultural awareness.

The findings also contribute to the literature on dialogue between local knowledge and science. When community knowledge, local artefacts, and everyday practices are brought into substantive engagement with scientific concepts, students enter a learning situation that requires negotiation of meaning rather than simple reception of finished ideas. In such a context, culture does not function merely as a label or illustration, but as part of the structure of the learning experience itself. The Panji Bobung mask became a site where physics, material knowledge, artistic practice, and cultural meaning could be read together. This helps explain why the experimental condition was more conducive to cultural care attitudes: it gave students repeated opportunities to see culture as something intellectually relevant to science, not merely socially valuable outside science.

The implications of these findings are important for ethnoscience-based physics education, particularly in teacher education institutions. If students' cultural orientations can change differently depending on instructional conditions, then instructional design cannot be treated as context-neutral. Learning that connects physics with local practices, cultural artefacts, and real problems in community life has the potential to create a more holistic learning experience. Such learning not only helps students understand concepts, but also shapes a more reflective way of seeing the relationship between science and culture. In the education of future teachers, this is especially relevant because stronger cultural orientations may influence how they later create inclusive learning environments, interpret students' experiences, and position science within socially diverse contexts (Gulya & Fehérvári, 2023; Romijn et al., 2021; Cherng & Davis, 2019).

At the same time, this article needs to be positioned carefully in relation to the earlier instrument study. The contribution of the previous article lay in the development and validation of the cultural care attitude instrument, whereas the present article moves toward the substantive question of how such affective outcomes change in actual instructional settings and whether that change differs across instructional conditions. In this sense, the article does not add primary evidence about the structure of the scale, but rather about the domain of learning outcomes. Its limitations also need to be acknowledged. The analysis still relies on total scores, the research context is limited to three higher education institutions in Yogyakarta, and the use of intact class-based groups means that selection bias could not be completely ruled out despite the use of pretest control and ANCOVA. The study also cannot fully isolate the relative contribution of each instructional component, including inquiry, ethnoscience, STEAM project work, cultural artefact engagement, and reflective discussion. Other moderators such as gender, prior cultural experience, lecturer differences, and previous exposure to local contexts were also not examined. For this reason, future research should be directed toward dimension-level analysis, broader populations, longitudinal designs, lecturer-controlled implementation, and more detailed investigation of which instructional elements most strongly influence the strengthening of cultural care attitudes.

CONCLUSION AND SUGGESTION

Cultural care attitudes improved in all instructional groups, but the strength of that improvement was not the same. The experimental group showed the highest gain, the largest magnitude of within-group change, and the highest adjusted posttest mean after baseline scores were controlled. These results suggest that the three instructional conditions were associated with different affective outcomes, with the experimental condition showing the strongest association with the strengthening of cultural care attitudes compared with the two other instructional conditions.

These findings suggest that ethnoscience-based physics learning and the integration of local cultural resources appeared to support not only cognitive learning purposes, but also the development of cultural orientations among pre-service physics teachers. However, this conclusion still needs to be read within the limits of the present study, which involved three higher education institutions in Yogyakarta and relied on total scores as the basis of analysis. Further studies are needed to test the consistency of these findings in broader populations, to examine changes at the dimensional level, and to investigate more closely which instructional elements are most influential in strengthening cultural care attitudes.

CONFLICTS OF INTEREST

The author declares that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, I.K. and F.L.S.; methodology, I.K. and F.L.S.; validation, I.K. and F.L.S.; formal analysis, I.K. and F.L.S.; investigation, I.K. and F.L.S.; resources, I.K. and F.L.S.; data curation, I.K. and F.L.S.; writing—original draft preparation, I.K. and F.L.S.; writing—review and editing, I.K. and F.L.S.; visualization, I.K. and F.L.S.; supervision, I.K. and F.L.S.; and project administration, I.K. and F.L.S. The authors have read and agreed to the published version of the manuscript.

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DECLARATION OF GENERATIVE AI SOURCES

During the preparation of this manuscript, the author used ChatGPT for language improvement, structure refinement, formatting assistance, and consistency checking. All generated content was carefully reviewed, revised, and verified by the author, who takes full responsibility for the final content of the manuscript.

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