Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

April 2026. Vol. 14, No. 2
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 1034-1049

Validity and Limited Trial of Physics Learning Tools Based on the Ethnoscience-Integrated Inquiry-Creative-Process Model to Improve Prospective Physics Teachers' Critical Thinking Skills

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Received: March 2026; Revised: March 2026; Published: April 2026

Abstract

This study aims to describe the validity and limited trial results of physics learning tools based on the ethnoscience-integrated Inquiry-Creative-Process (ICP) model to improve prospective physics teachers' critical thinking skills. This research employed a development research design and produced semester learning plans and learning scenarios, teaching materials or modules, and a critical thinking test instrument. The learning tools were validated by three expert validators based on content validity and construct validity. The limited trial used a one-group pretest-posttest design involving 29 prospective physics teachers. Data were analyzed descriptively using mean scores and n-gain, and inferentially using a paired sample t-test and the Wilcoxon signed-rank test. The validation results showed an average content validity score of 4.05 and an average construct validity score of 3.99, both categorized as valid. The limited trial results showed that the CTs score increased from 10.41 to 25.55 with an n-gain of 0.70. The average CTi score also increased from 1.30 to 3.19 with an n-gain of 0.70. The increase in CTs was significant based on the paired sample t-test, while all CTi indicators showed significant improvement based on the Wilcoxon signed-rank test. These findings indicate that physics learning tools based on the ethnoscience-integrated ICP model are valid and can improve prospective physics teachers' critical thinking skills in a limited trial context.

Keywords: Critical thinking; Ethnoscience; Inquiry-creative-process; Prospective physics teachers; Learning tools

How to Cite: Verawati, N. N. S. P., Harjono, A., & Wahyudi, W. (2026). Validity and Limited Trial of Physics Learning Tools Based on the Ethnoscience-Integrated Inquiry-Creative-Process Model to Improve Prospective Physics Teachers' Critical Thinking Skills. *Prisma Sains: Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *14*(2), 1034–1049. https://doi.org/10.33394/j-ps.v14i2.20995

https://doi.org/10.33394/j-ps.v14i2.20995

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INTRODUCTION

Critical thinking skills are among the essential competencies in higher education, particularly in physics teacher education programs. In science learning, critical thinking is not only related to the ability to answer questions, but also includes the ability to analyze information, construct inferences, evaluate evidence, and make decisions based on scientific considerations. This competence becomes increasingly important for prospective teachers because they will act as learning facilitators who not only transfer knowledge but also shape students' ways of thinking. Therefore, strengthening prospective teachers' critical thinking skills is an important part of improving the quality of science learning in the future (Tiruneh et al., 2017; Prayogi et al., 2018; Ma & Luo, 2021).

Although the urgency of critical thinking has been widely emphasized, prospective teachers' critical thinking skills remain a problem in physics learning. Several studies have shown that prospective teachers' critical thinking skills have not developed optimally and still require more directed learning interventions (Fitriani et al., 2019; Prayogi & Verawati, 2020).

One frequently identified cause is that learning practices do not yet fully encourage students to construct knowledge through inquiry, argumentation, evaluation, and problem-solving processes. Physics learning is often still oriented toward conceptual mastery and procedural problem solving, while activities that explicitly train students to question phenomena, evaluate evidence, and make scientific decisions have not received sufficient attention (Verawati et al., 2021).

Various approaches have been developed to train critical thinking skills in science learning. These include student-centered multimodal learning, inquiry-based learning, authentic problem solving, the use of learning technology, and evaluative processes in learning (Soubra et al., 2022; Verawati et al., 2020; Evendi et al., 2022; Bilad et al., 2022; Fitriani et al., 2022). Among these approaches, inquiry-based learning has strong relevance because it positions students as active subjects in the process of identifying problems, formulating assumptions, collecting information, testing ideas, and drawing conclusions. However, inquiry-based learning needs to be strengthened with scientific creativity so that students do not merely follow inquiry procedures but are also able to design more flexible and productive ways of thinking and solving problems (Wahyudi et al., 2018; Wahyudi et al., 2019).

One learning model that integrates inquiry processes and scientific creativity is the Inquiry-Creative-Process (ICP) model. The ICP model was developed as an inquiry-based learning model that incorporates scientific creativity processes to support prospective physics teachers' critical thinking skills (Wahyudi et al., 2018; Wahyudi et al., 2019). This model consists of five main phases: preparation and problem identification, hypothesis formulation, creative experiment design, creative scientific problem solving, and creative product design. These phases provide opportunities for students not only to understand physics concepts, but also to connect concepts with problems, construct explanations, test possible solutions, and produce ideas or products based on scientific reasoning. Thus, ICP can be viewed as a learning framework with the potential to train critical thinking skills because its process requires higher-order cognitive engagement.

However, inquiry-based learning and scientific creativity become more meaningful when connected to students' real-life contexts. Physics learning is often presented in an abstract manner and is insufficiently connected to students' sociocultural experiences. In fact, students live in environments rich in cultural practices, local technologies, and community knowledge that can serve as learning resources. The disconnection between physics concepts and real-life contexts may cause students to understand concepts formally, but not necessarily be able to use them to explain phenomena close to community life. Therefore, physics learning needs to consider sociocultural aspects, including cultural values, local wisdom, and community practices as contexts for building scientific understanding (Sudarmin et al., 2019; Garcia et al., 2020).

The integration of science with culture and local wisdom is known as ethnoscience. Ethnoscience refers to a system of community knowledge that develops within a particular culture and is related to understandings of nature, the environment, and the relationship between humans and nature (Rist & Dahdouh-Guebas, 2006; Zidny et al., 2020). In science education, ethnoscience can serve as a bridge between local knowledge and modern scientific knowledge. Ethnoscience-based learning does not position culture as a mere supplement, but as an authentic context for developing conceptual understanding, scientific reasoning, scientific literacy, and critical thinking skills (Dewi et al., 2021; Risdianto et al., 2020; Zidny & Eilks, 2022). Through ethnoscience, students can examine cultural phenomena, identify the underlying physics concepts, and construct scientific explanations of community practices.

In physics learning, various ethnoscience phenomena can be used as learning resources. For example, traditional transportation can be linked to the concepts of kinematics and dynamics of motion, the traditional art of Gendang Beleq can be linked to sound waves, clay water containers or *bong* used for ablution can be linked to fluid concepts, the floating village

of the Bajo tribe and floating markets can be linked to fluid mechanics, and the tradition of carrying objects on the head can be linked to the concept of object equilibrium. These phenomena show that physics concepts are not only found in laboratories or textbooks, but are also embedded in cultural practices and community life. When students examine these phenomena through a creative inquiry process, they are required to analyze problems, construct inferences, evaluate the relationship between local concepts and scientific concepts, and make decisions based on accountable arguments.

The integration of the ICP model and ethnoscience is important because the two complement each other. ICP provides an inquiry-based and scientific creativity-oriented learning sequence, while ethnoscience provides an authentic context that is close to students' lives. By integrating both, physics learning can be directed toward a more contextual, active, reflective, and critical process. This is consistent with the view that creativity in learning can optimize students' thinking processes, especially when learning provides opportunities for students to explore problems, develop ideas, and construct scientific solutions (Iskandar et al., 2020). Therefore, physics learning tools based on ethnoscience-integrated ICP need to be developed so that the learning process is not only oriented toward conceptual understanding, but also toward strengthening prospective physics teachers' critical thinking skills.

The development of learning tools is an important part of ensuring that a learning model can be implemented systematically. Learning tools are a set of designs used to guide the implementation of learning so that the expected objectives can be achieved (Suarniati et al., 2018). Learning tools generally include syllabi, lesson plans, worksheets, test instruments, and teaching materials or learning modules (Ubaidah & Aminudin, 2019; Putra et al., 2019). In this study, the learning tools developed include semester learning plans and learning scenarios, teaching materials or modules, and a critical thinking test instrument. All of these tools need to be designed consistently based on the ethnoscience-integrated ICP model so that the objective of developing critical thinking skills is reflected in the planning, activities, materials, and evaluation of learning.

The developed learning tools cannot be used directly without undergoing a validation process. In development research, validity is one of the important criteria for determining the quality of the developed product (Akker et al., 2013). The validity of learning tools can be examined through content validity and construct validity. Content validity indicates the suitability of the tool components with learning needs, objectives, and the novelty of knowledge, while construct validity indicates the consistency of relationships among tool components based on the theoretical framework used (Akker et al., 2013). In the context of test instruments, content validity also needs to consider domain definition, domain representation, and domain relevance so that the test items truly represent the construct being measured (Sireci & Faulkner-Bond, 2014). Therefore, expert validation is an important stage to ensure that physics learning tools based on the ethnoscience-integrated ICP model are appropriate for use in learning.

In addition to expert validation, a limited trial is also needed to obtain an initial picture of the potential of the learning tools in training critical thinking skills. A limited trial is important because the theoretical and construct validity of the tools does not fully show how the tools work when implemented with students. Through a limited trial, researchers can observe changes in students' critical thinking skills based on pretest and posttest results. In this study, critical thinking skills were examined through the indicators of analysis, inference, evaluation, and decision-making, as well as individual critical thinking performance. Such data are important as an initial basis for assessing the potential of the tools, although claims of effectiveness should remain limited because the trial was conducted on a restricted scale.

Based on the above discussion, this study aims to describe the validity and limited trial results of physics learning tools based on the ethnoscience-integrated Inquiry-Creative-Process model to improve prospective physics teachers' critical thinking skills. Specifically, this study

examines the content validity and construct validity of learning tools consisting of semester learning plans and learning scenarios, teaching materials or modules, and a critical thinking test instrument. In addition, this study examines the results of a limited trial of the learning tools based on changes in prospective physics teachers' critical thinking skills in the indicators of analysis, inference, evaluation, and decision-making. Thus, the findings of this study are expected to contribute to the development of physics learning tools that are valid, contextual, and potentially supportive of strengthening prospective teachers' critical thinking skills through the integration of ICP and ethnoscience.

METHOD

This study employed a development research design aimed at producing physics learning tools based on the ethnoscience-integrated Inquiry-Creative-Process (ICP) model to improve prospective physics teachers' critical thinking skills. The products developed in this study consisted of semester learning plans (RPS) and learning scenarios, teaching materials or modules, and a critical thinking test instrument. This study was not only directed at producing learning products, but also at examining the validity of the learning tools through expert judgment and testing the improvement of students' critical thinking skills through a limited trial. Therefore, the research design consisted of two main stages: the development and validation of learning tools, and a limited trial using a one-group pretest-posttest design.

The development of the learning tools adapted the development research framework proposed by Gall et al. (2007), modified according to the needs of this study. The development stages included a preliminary study and information gathering, planning the development of learning tools, preparing the learning tools, validating the tools by experts, revising the tools based on the validation results, and conducting a limited trial. The preliminary study was conducted to identify the need for developing learning tools that could train prospective physics teachers' critical thinking skills. The results of the preliminary study served as the basis for designing learning tools based on the ICP model integrated with ethnoscience phenomena.

The learning tools were developed based on the five phases of the Inquiry-Creative-Process model, namely preparation and problem identification, hypothesis formulation, creative experiment design, creative scientific problem solving, and creative product design. In this study, the ICP phases were integrated with ethnoscience phenomena relevant to physics concepts. This integration was intended to ensure that learning did not only emphasize conceptual mastery, but also encouraged students to perform analysis, inference, evaluation, and decision-making based on scientific phenomena rooted in culture and community life.

The subjects involved in this study consisted of three expert validators and 29 prospective physics teachers. The expert validators assessed the feasibility of the learning tools in terms of content validity and construct validity. Meanwhile, the prospective physics teachers were involved in the limited trial to measure the improvement of critical thinking skills after participating in learning using the developed tools. In the limited trial, students were given a pretest before the learning process and a posttest after the learning process.

The research instruments consisted of learning tool validation sheets and a critical thinking test. The validation sheets were used to assess the content validity and construct validity of three types of learning tools: semester learning plans and learning scenarios, teaching materials or modules, and a critical thinking test instrument. Content validity was directed at assessing the suitability of the tool components with learning needs, novelty, and relevance to the development objectives. Construct validity was directed at assessing the consistency of relationships among the components of the learning tools based on the framework of the ethnoscience-integrated ICP model. This validity assessment was based on the view that a good development product should contain components that are grounded in current knowledge and consistently connected to one another (Akker et al., 2013). More

specifically, construct validity refers to the extent to which the operationalization of a construct or concept is supported by a clear theoretical basis (Cronbach & Meehl, 1955; McGrath, 2005).

The validation sheet for the semester learning plans and learning scenarios contained content validity indicators that assessed the suitability of the plans and scenarios with the framework of the ethnoscience-integrated ICP model, learning outcomes, expected final competencies, material achievement indicators, and the function of the tools in supporting students' critical thinking performance. The construct validity aspect of the semester learning plans and learning scenarios assessed the consistency of relationships among the semester learning plans, learning scenarios, learning outcomes, expected final competencies, study materials, indicators, ICP model phases, ethnoscience phenomena, language use, and information organization.

The validation sheet for the teaching materials assessed the suitability of the materials with the ethnoscience-integrated ICP model, the relationship between the materials and learning competencies, the integration of ethnoscience content with physics concepts, the availability of exploratory activities, and the ability of the materials to foster curiosity and critical thinking. The construct validity of the teaching materials assessed the consistency of the presentation of ethnoscience phenomena, the accuracy of facts, concepts, principles, and theories, the coherence of presentation, the use of SI units, and the appropriateness of language.

The critical thinking test instrument was validated by considering both content validity and construct validity. The content validity of the test instrument referred to three domains: domain definition, domain representation, and domain relevance, as proposed by Sireci and Faulkner-Bond (2014). Domain definition was used to assess the suitability of the test content with the operational definition of critical thinking. Domain representation was used to assess the representativeness of the cognitive specifications of critical thinking in the test items. Domain relevance was used to assess the relevance of each test item to the content domain contained in the teaching materials. The construct validity of the test instrument assessed the consistency of the instrument in measuring critical thinking skills according to the material taught, the accuracy of facts and concepts, the relationship with learning indicators, the use of symbols and units, and the clarity of language.

Validation data were obtained through validators' assessments using a five-point scale. A score of 5 indicated that the validation item was highly consistent with the aspect being measured, 4 indicated consistent, 3 indicated moderately consistent, 2 indicated less consistent, and 1 indicated inconsistent. The validation data were analyzed descriptively by calculating the average score for each validation aspect of each learning tool. The criteria for determining the validity of the learning tools are presented in Table 1.

Table 1. Validity criteria for learning tools

Score interval	Criteria
$x > 4.21$	Very valid
$3.40 < x \leq 4.21$	Valid
$2.60 < x \leq 3.40$	Moderately valid
$1.79 < x \leq 2.60$	Less valid
$x \leq 1.79$	Invalid

In addition to quantitative data, qualitative suggestions and feedback from the validators were used as the basis for revising and improving the learning tools before they were implemented in the limited trial. The revisions were intended to improve the suitability of content, construct consistency, readability, and integration among the ICP model, ethnoscience phenomena, and the objective of developing critical thinking skills.

The limited trial was conducted to examine the improvement of prospective physics teachers' critical thinking skills after participating in learning using the ethnoscience-integrated ICP physics learning tools. Critical thinking skills were measured using two parameters: the

average critical thinking indicator score (CTi) and individual critical thinking performance (CTs). The CTi indicators consisted of analysis, inference, evaluation, and decision-making. Measurement was conducted using a pretest and posttest. The pretest was administered before students participated in learning using the developed tools, while the posttest was administered after the learning process was completed.

The category of critical thinking skills was determined based on the CTi and CTs score intervals. CTi was used to describe students' critical thinking achievement based on indicators, while CTs was used to describe individual critical thinking performance. The categories of critical thinking skills are presented in Table 2.

Table 2. Categories of critical thinking skills based on CTi and CTs

CTi score interval	CTs score interval	Category
CTi > 3.21	CTs > 25.60	Very critical
2.40 < CTi ≤ 3.21	19.20 < CTs ≤ 25.60	Critical
1.60 < CTi ≤ 2.40	12.80 < CTs ≤ 19.20	Moderately critical
0.80 < CTi ≤ 1.60	6.41 < CTs ≤ 12.80	Less critical
CTi ≤ 0.80	CTs ≤ 6.41	Not critical

The research data were analyzed using descriptive and inferential quantitative analyses. The validation data of the learning tools were analyzed descriptively by calculating the average scores of content validity and construct validity from the three validators. The average scores were then converted into the validity criteria for learning tools as presented in Table 1. Qualitative suggestions and feedback from the validators were used as the basis for revising and improving the learning tools before the limited trial was conducted.

The data on students' critical thinking skills in the limited trial were analyzed based on pretest and posttest scores. The analysis was conducted using two parameters: individual critical thinking performance (CTs) and the average critical thinking indicator score (CTi). CTi consisted of four indicators: analysis, inference, evaluation, and decision-making. The pretest and posttest scores were first analyzed descriptively using total scores, mean scores, standard deviations, critical thinking categories, and n-gain. The n-gain analysis was used to determine the magnitude of improvement in students' critical thinking skills after participating in learning using the ethnoscience-integrated ICP physics learning tools. The n-gain formula used in this study was as follows.

$$g = (\text{posttest score} - \text{pretest score}) / (\text{maximum score} - \text{pretest score})$$

The n-gain values were interpreted based on improvement categories: high if $g \geq 0.70$, medium if $0.30 \leq g < 0.70$, and low if $g < 0.30$ (Hake, 1999). In this study, n-gain was used to describe the magnitude of improvement in critical thinking skills descriptively.

To determine the significance of the improvement in critical thinking skills, inferential analysis was conducted on the pretest and posttest scores. Before determining the appropriate difference test, the Shapiro-Wilk normality test was conducted on the difference scores between posttest and pretest. For the CTs parameter, if the difference scores were normally distributed, the difference between pretest and posttest scores was analyzed using a paired sample t-test. In addition to the significance value, the effect size was calculated using Cohen's dz to determine the magnitude of the difference between the pretest and posttest scores in the limited trial group. Cohen's dz was calculated by dividing the mean difference between posttest and pretest scores by the standard deviation of the difference scores.

For the CTi parameter, the normality test was conducted on the difference scores between pretest and posttest for each critical thinking indicator. If the difference scores for an indicator were not normally distributed, the difference between pretest and posttest scores was analyzed using the Wilcoxon signed-rank test. The Wilcoxon signed-rank test was used to examine the improvement of each critical thinking indicator in accordance with the characteristics of the data distribution. All statistical tests were conducted at a significance level of 0.05. The

inferential analysis results were used to strengthen the interpretation of the improvement in critical thinking skills, while n-gain was used to describe the magnitude of the improvement descriptively.

RESULTS AND DISCUSSION

The development of physics learning tools based on the ethnoscience-integrated Inquiry-Creative-Process (ICP) model began with a preliminary study and information gathering. This stage served as the basis for designing learning tools that were not only oriented toward mastery of physics concepts, but also directed at training prospective physics teachers' critical thinking skills. This need is consistent with the view that learning tools are an important component in guiding the learning process so that learning objectives can be achieved systematically (Suarniati et al., 2018; Ubaidah & Aminudin, 2019; Putra et al., 2019). In this study, the developed tools included semester learning plans and learning scenarios, teaching materials or modules, and a critical thinking test instrument.

The ICP model was operationalized through five learning phases: preparation and problem identification, hypothesis formulation, creative experiment design, creative scientific problem solving, and creative product design. These phases were integrated with ethnoscience phenomena relevant to physics concepts, such as traditional transportation related to the concepts of kinematics and dynamics of motion, *Gendang Beleq* related to sound waves, clay water containers or *bong* related to fluid concepts, the floating village of the Bajo tribe and floating markets related to fluid mechanics, and the tradition of carrying objects on the head related to object equilibrium. This integration is based on the view that ethnoscience can serve as a bridge between local knowledge and modern scientific knowledge, particularly because ethnoscience contains community knowledge systems about nature, the environment, and the relationship between humans and nature (Rist & Dahdouh-Guebas, 2006; Zidny et al., 2020; Zidny & Eilks, 2022).

The validation of the learning tools was conducted by three expert validators by assessing the aspects of content validity and construct validity. Content validity was used to assess the suitability of the tool components with learning needs, novelty, and relevance to the objective of developing critical thinking skills. Construct validity was used to assess the consistency of relationships among the components of the tools based on the framework of the ethnoscience-integrated ICP model. The emphasis on these two aspects is consistent with the principle of development research that high-quality learning products should meet the requirements of both content validity and construct validity (Akker et al., 2013). More specifically, construct validity also indicates the extent to which the concepts or constructs used in the tools are operationalized consistently based on a clear theoretical framework (Cronbach & Meehl, 1955; McGrath, 2005). The validation results of the learning tools are presented in Figure 1.

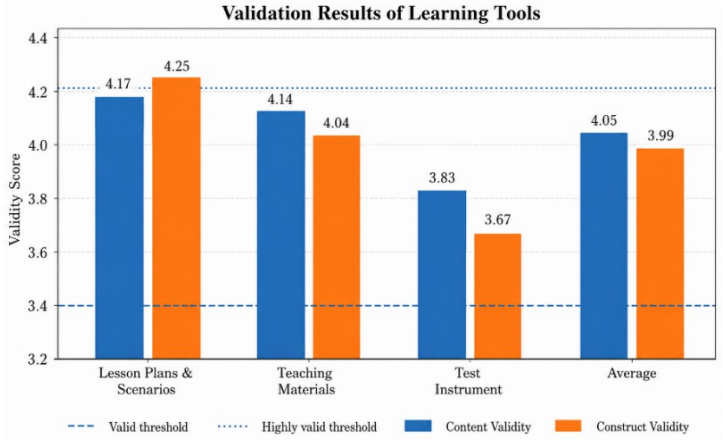


Figure 1. Validation results of physics learning tools based on the ethnoscience-integrated ICP model in terms of content validity and construct validity

Based on Figure 1, the average content validity score of all learning tools was 4.05, and the average construct validity score was 3.99. Both scores were categorized as valid. These findings indicate that the physics learning tools based on the ethnoscience-integrated ICP model met the feasibility criteria in terms of both content and construct. This means that the developed tools were considered suitable for learning needs, relevant to the objective of developing critical thinking skills, and consistent in the relationships among their components. These findings strengthen the position of the tools as development products that are feasible for use in the limited trial stage because they have met the basic quality criteria for educational development products (Akker et al., 2013).

More specifically, the semester learning plans and learning scenarios obtained an average content validity score of 4.17, categorized as valid, and a construct validity score of 4.25, categorized as very valid. These scores indicate that the semester learning plans and learning scenarios reflected a learning planning framework that was consistent with the ethnoscience-integrated ICP model. The learning outcomes, expected final competencies, study materials, indicators, and learning phases were considered logically connected to support students' critical thinking skills. This finding is important because semester learning plans and learning scenarios serve as the operational basis for implementing learning. Without valid learning planning, the direction of learning may become inconsistent with the objective of developing critical thinking skills. This finding is in line with Otaya et al. (2020), who emphasized the importance of construct validity in learning planning instruments and tools, and with Fitriani et al. (2022), who showed that valid learning tools are an important prerequisite for training critical thinking skills.

The teaching materials obtained an average content validity score of 4.14 and a construct validity score of 4.04. Both were categorized as valid. These results indicate that the developed teaching materials contained content relevant to the ethnoscience-integrated ICP model and supported physics learning oriented toward critical thinking. The teaching materials did not only present physics concepts, but also connected them with ethnoscience phenomena as learning resources. This integration is important because ethnoscience-based learning can help students understand that physics concepts are not only found in textbooks or laboratories, but are also embedded in cultural practices and community life. Learning that connects science with cultural contexts can support scientific literacy, scientific reasoning, and more contextual conceptual understanding (Dewi et al., 2021; Risdianto et al., 2020; Zidny et al., 2020).

From the construct perspective, the score of 4.04 indicates that the teaching materials were organized logically and consistently. The presentation of ethnoscience phenomena, exploratory activities, physics concepts, principles, theories, symbols, and units was considered appropriate for learning needs. However, the teaching materials were still categorized as valid and had not yet reached the very valid category. This means that the teaching materials still have room for improvement, particularly in strengthening the connection between ethnoscience phenomena, creative inquiry activities, and critical thinking indicators. This condition is reasonable in development research because teaching materials that integrate cultural contexts and scientific concepts require careful construction so that they do not merely present cultural examples, but genuinely encourage students to conduct analysis, evaluation, and scientific decision-making. The importance of teaching material validity has also been emphasized by Yunita and Agustini (2020), Oktarina et al. (2018), and Mohamed Abdelmohsen (2020), who showed that valid teaching materials or modules contribute to the quality of learning and the development of higher-order thinking skills.

The test instrument obtained an average content validity score of 3.83 and a construct validity score of 3.67. Both were categorized as valid, although they were the lowest scores compared with the other tools. This finding indicates that the critical thinking test instrument was feasible to use, but it remains the component that requires the most attention in further

development. This is understandable because constructing a critical thinking instrument is more complex than preparing learning plans or teaching materials. The test instrument must not only be relevant to the materials, but also be able to represent the critical thinking construct accurately. In the context of the content validity of test instruments, Sireci and Faulkner-Bond (2014) emphasized the importance of domain definition, domain representation, and domain relevance as the basis for ensuring that test items truly represent the construct being measured.

The content validity score of the test instrument, 3.83, indicates that the test items were consistent with the operational definition of critical thinking and relevant to the teaching materials. However, the lower score compared with the semester learning plans and teaching materials indicates that the representation of critical thinking indicators in the test items still needs to be strengthened. The construct validity score of 3.67 indicates that the test instrument was consistent in measuring critical thinking skills according to the materials taught, although the relationship among indicators, physics content, and ethnoscience contexts can still be sharpened. This is in line with Tiruneh et al. (2017), who showed that the development of critical thinking tests in physics requires construct accuracy and content-context suitability. Thus, the validation results of the test instrument do not indicate infeasibility, but provide a basis for continuous revision so that the instrument becomes more sensitive in capturing students' critical thinking performance.

In general, the validation results indicate that the physics learning tools based on the ethnoscience-integrated ICP model were feasible for use in the limited trial stage. The validation pattern shows that the semester learning plans and learning scenarios obtained the highest scores, the teaching materials were in the middle position, and the test instrument obtained the lowest scores. This pattern indicates that the learning design was strong in terms of planning and sufficiently strong in terms of teaching materials, while the critical thinking assessment tool still needs further refinement. In development research, such results are acceptable as long as the tools are categorized as valid and revisions are made based on validators' suggestions before the trial stage (Akker et al., 2013; Muslim et al., 2021).

After the tools were declared valid, a limited trial was conducted with 29 prospective physics teachers. This trial aimed to obtain an overview of the improvement in students' critical thinking skills after participating in learning using the physics learning tools based on the ethnoscience-integrated ICP model. Critical thinking skills were analyzed using two parameters: individual critical thinking performance (CTs) and the average critical thinking indicator score (CTi). The descriptive statistics of CTs scores are presented in Table 3.

Table 3. Descriptive statistics of CTs among prospective physics teachers

Parameter	n	Total score	Mean	Standard deviation	Category
Pretest	29	302	10.41	2.01	Less critical
Posttest	29	741	25.55	1.64	Critical
Posttest-pretest difference	29	439	15.14	2.42	-
N-gain	29	-	0.70	0.08	Medium

Based on Table 3, students' average CTs score in the pretest was 10.41, categorized as less critical. After learning using the physics learning tools based on the ethnoscience-integrated ICP model, the average posttest score increased to 25.55, categorized as critical. The mean difference between the pretest and posttest scores was 15.14. The n-gain value of 0.70 was in the medium category. Descriptively, these results indicate that students' critical thinking skills improved after participating in learning using the developed tools. The use of n-gain in this context is relevant because n-gain can describe the magnitude of learning improvement from pretest to posttest proportionally to the maximum score that may be achieved (Hake, 1999).

To determine whether the increase in CTs scores was statistically significant, a normality test was first conducted on the posttest-pretest difference scores. The Shapiro-Wilk test showed

that the difference scores were normally distributed, W = 0.958, p = 0.287. Since the p value was greater than 0.05, the analysis was continued using a paired sample t-test. The results of the paired sample t-test are presented in Table 4.

Table 4. Paired sample t-test results for CTs scores

Parameter	Mean diff.	SD diff.	95% CI	t	df	p	Cohen's dz
Posttest-pretest	15.14	2.42	14.22 to 16.06	33.74	28	< 0.001	6.27

Based on Table 4, the paired sample t-test showed a significant difference between the pretest and posttest CTs scores, t(28) = 33.74, p < 0.001. This result indicates that prospective physics teachers' critical thinking skills improved significantly after participating in learning using the physics learning tools based on the ethnoscience-integrated ICP model. The Cohen's dz value of 6.27 indicates a very large difference within the limited trial group. However, the interpretation of this effect size should be made cautiously because the study used a one-group design without a control group. Thus, this result indicates a significant improvement in the limited trial context, but it is not sufficient to conclude full causal effectiveness.

In addition to CTs, critical thinking skills were also analyzed using the CTi parameter, which included four indicators: analysis, inference, evaluation, and decision-making. The CTi results based on pretest, posttest, and n-gain scores are presented in Table 5.

Table 5. CTi results based on pretest, posttest, and n-gain scores

CT indicator	Pretest	Category	Posttest	Category	N-gain	Category
Analysis	1.22	Less critical	3.33	Very critical	0.76	High
Inference	1.17	Less critical	3.14	Critical	0.70	Medium
Evaluation	1.34	Less critical	3.12	Critical	0.67	Medium
Decision-making	1.47	Less critical	3.19	Critical	0.68	Medium
Average	1.30	Less critical	3.19	Critical	0.70	Medium

Table 5 shows that before learning using the ethnoscience-integrated ICP tools, students' average CTi score was 1.30, categorized as less critical. After learning, the average CTi score increased to 3.19, categorized as critical. The improvement occurred in all critical thinking indicators measured. The average n-gain score of 0.70 was in the medium category. These findings indicate that improvement did not only occur in the total individual score, but also across critical thinking indicators, including analysis, inference, evaluation, and decision-making.

The highest improvement occurred in the analysis indicator, with the pretest score increasing from 1.22 to 3.33 and an n-gain of 0.76, categorized as high. This result indicates that learning based on ethnoscience-integrated ICP most strongly encouraged students' ability to identify problems, sort information, and connect phenomena with relevant physics concepts. This can be explained by the characteristics of the early phase of ICP, which emphasizes problem finding or problem identification. When students are confronted with ethnoscience phenomena, they need to observe, identify scientific elements within cultural practices, and determine the underlying physics concepts. These activities directly require analytical ability. This finding is consistent with Wahyudi et al. (2018, 2019), who showed that the integration of creative processes in inquiry learning can support prospective teachers' critical thinking skills.

The inference indicator increased from 1.17 to 3.14 with an n-gain of 0.70, categorized as medium. This improvement shows that students began to be able to draw conclusions or assumptions based on available information. In the ICP model, inference skills are mainly trained through the phases of hypothesis formulation and creative experiment design. Students are not only required to understand phenomena, but also to predict causal relationships and formulate scientific assumptions that can be tested. This process is consistent with the

characteristics of inquiry learning, which emphasizes investigation, reasoning, and the construction of scientific explanations (Aditomo & Klieme, 2020; Cheung et al., 2020).

The evaluation indicator increased from 1.34 to 3.12 with an n-gain of 0.67, categorized as medium. The improvement in this indicator indicates that students developed their ability to assess information, compare alternative explanations, and consider the accuracy of the concepts used. However, the n-gain score for evaluation was still lower than those for analysis and inference. This suggests that evaluation skills require longer habituation. Evaluation requires students not only to understand concepts, but also to assess the strength of evidence, the accuracy of arguments, and the suitability of scientific explanations to the phenomena being examined. In science learning, evaluation skills are an important part of critical thinking because students need to examine the quality of information before drawing conclusions or making decisions (Tiruneh et al., 2017; Prayogi et al., 2018).

The decision-making indicator increased from 1.47 to 3.19 with an n-gain of 0.68, categorized as medium. This result indicates that students began to be able to use information and physics concepts to determine decisions or solutions to the problems given. In the ICP model, this skill is related to the phases of creative scientific problem solving and creative product design. Students need to choose alternative solutions, consider consequences, and formulate decisions based on scientific reasoning. Although this indicator improved, the results still indicate the need to strengthen argumentation and reflection activities so that students' decisions are not merely intuitive, but are based on data, concepts, and strong scientific reasoning. This is in line with Evendi et al. (2022), who emphasized the importance of problem-based learning in training critical thinking skills through reasoning and decision-making processes.

To examine the improvement in each CTi indicator, a normality test was conducted on the posttest-pretest difference scores for each critical thinking indicator. The normality test results showed that the difference scores for the indicators were not all normally distributed. Therefore, the differences between pretest and posttest scores for the CTi indicators were analyzed using the Wilcoxon signed-rank test. The results of the Wilcoxon test are presented in Table 6.

Table 6. Wilcoxon signed-rank test results for CTi indicators

Critical thinking indicator	Wilcoxon statistic	p	Decision
Analysis	0.00	< 0.001	Significant
Inference	0.00	< 0.001	Significant
Evaluation	0.00	< 0.001	Significant
Decision-making	0.00	< 0.001	Significant

Based on Table 6, all critical thinking indicators showed significant improvement between the pretest and posttest, with $p < 0.001$. These results strengthen the descriptive and n-gain findings that the physics learning tools based on the ethnoscience-integrated ICP model not only improved the total critical thinking score, but also improved each measured critical thinking indicator. Thus, the improvement in students' critical thinking skills occurred comprehensively in the aspects of analysis, inference, evaluation, and decision-making.

Conceptually, the improvement in CTs and CTi can be explained by the characteristics of the ICP model, which positions students as active participants in the learning process. Students do not merely receive information from lecturers, but are directed to identify problems, formulate hypotheses, design experiments or inquiry strategies, solve problems, and design products. Such activities are consistent with the demands of critical thinking because students must use knowledge to process information, evaluate possible solutions, and make decisions. This finding supports the results of Wahyudi et al. (2018, 2019), who showed that scientific creativity in inquiry learning can promote prospective teachers' critical thinking skills.

The integration of ethnoscience is also an important factor in explaining the improvement in critical thinking skills. Ethnoscience phenomena provide an authentic context that makes physics learning closer to students' lives. When students examine cultural phenomena from a physics perspective, they engage in a process of translating local knowledge into scientific explanations. This process requires students to ask questions, identify relevant concepts, construct reasoning, and evaluate the suitability of explanations. Thus, ethnoscience functions as a context that strengthens critical thinking activities, rather than merely serving as cultural examples in learning. This view is consistent with Rist and Dahdouh-Guebas (2006), Zidny et al. (2020), Dewi et al. (2021), and Zidny and Eilks (2022), who emphasize that local knowledge can serve as an important source for contextual and meaningful science learning.

The findings of this study also show that the validity of the learning tools has an important relationship with the success of the limited trial. Tools that have been assessed as valid in terms of content and construct provide a stronger basis for learning implementation. Semester learning plans and learning scenarios that are very valid in terms of construct help ensure that the learning flow follows the ICP syntax and the objective of developing critical thinking. Valid teaching materials provide content and activities that connect ethnoscience phenomena with physics concepts. A valid test instrument enables critical thinking skills to be measured in a more directed manner. Thus, tool validation is not merely an administrative procedure, but an important prerequisite before the tools are implemented in learning (Akker et al., 2013; Otaya et al., 2020; Muslim et al., 2021).

Although the limited trial results showed a significant improvement in critical thinking skills, these findings should still be interpreted cautiously. The trial design used in this study was a one-group pretest-posttest design without a control group. Therefore, the improvement results cannot yet be claimed as strong comparative evidence of effectiveness. The increase from pretest to posttest scores, n-gain, paired sample t-test, and Wilcoxon signed-rank test indicates a positive result after using the tools, but these findings cannot fully eliminate the possibility of other factors beyond the treatment. Thus, the findings of this study are more appropriately interpreted as evidence that the physics learning tools based on the ethnoscience-integrated ICP model are valid and show a significant improvement in critical thinking skills in the context of a limited trial.

Based on the overall results, the physics learning tools based on the ethnoscience-integrated ICP model can be considered feasible for use in limited learning contexts and can be continued to broader implementation stages. Content validity and construct validity show that the tools meet theoretical and structural feasibility, while the limited trial results show improvement in students' critical thinking skills both descriptively and inferentially. However, further development is still needed, particularly in refining the test instrument and expanding effectiveness testing using a stronger experimental design. Future studies may involve a control group, a larger number of subjects, and more comprehensive statistical analyses to obtain stronger evidence regarding the effectiveness of learning tools based on the ethnoscience-integrated ICP model.

CONCLUSION

The physics learning tools based on the ethnoscience-integrated Inquiry-Creative-Process (ICP) model developed in this study were declared valid based on the assessment of three expert validators. The validity of the tools was examined in terms of content validity and construct validity across three main components: semester learning plans and learning scenarios, teaching materials or modules, and a critical thinking test instrument. The average content validity score of all learning tools was 4.05, and the average construct validity score was 3.99, both categorized as valid. The semester learning plans and learning scenarios obtained the highest construct validity score of 4.25, categorized as very valid, indicating that

the learning planning sequence was consistently aligned with the ICP syntax, ethnoscience contexts, and the objective of developing prospective physics teachers' critical thinking skills.

The limited trial involving 29 prospective physics teachers showed an improvement in critical thinking skills after the implementation of the learning tools. The average CTs score increased from 10.41 in the pretest, categorized as less critical, to 25.55 in the posttest, categorized as critical. The n-gain value of 0.70 indicated a medium level of improvement. The paired sample t-test also showed a significant difference between pretest and posttest scores, indicating that the developed learning tools demonstrated an improvement in students' critical thinking skills within the context of a limited trial.

The improvement in critical thinking skills was also observed across all CTi indicators, namely analysis, inference, evaluation, and decision-making. The average CTi score increased from 1.30, categorized as less critical, to 3.19, categorized as critical, with an average n-gain of 0.70. The analysis indicator showed the highest improvement, with an n-gain of 0.76 in the high category, while inference, evaluation, and decision-making were in the medium category. These findings indicate that the integration of the ICP model with ethnoscience can serve as a relevant learning strategy for connecting physics concepts with cultural phenomena, while also encouraging students to engage in scientific analysis, reasoning, evaluation, and decision-making.

LIMITATIONS

This study has several limitations that need to be considered. The trial of the learning tools was still limited to one group of 29 prospective physics teachers and used a one-group pretest-posttest design without a control group. Therefore, although the results showed an improvement in critical thinking skills both descriptively and inferentially, the findings cannot yet be fully used to draw strong causal conclusions regarding effectiveness. In addition, the test instrument obtained the lowest validity score compared with the semester learning plans, learning scenarios, and teaching materials, indicating that further refinement is still needed so that the test items become more sensitive in representing critical thinking indicators and ethnoscience contexts.

RECOMMENDATIONS

Future research is recommended to test physics learning tools based on the ethnoscience-integrated ICP model with a broader group of participants and to use an experimental design involving a control group, so that the effectiveness of the tools can be examined more rigorously. Further development should also focus on improving the critical thinking test instrument, particularly in terms of the representation of analysis, inference, evaluation, and decision-making indicators within ethnoscience-based phenomena. In addition, the learning tools can be expanded to other physics topics and developed with more diverse local ethnoscience phenomena so that their implementation becomes more contextual, adaptive, and relevant for prospective physics teachers' learning.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the expert validators who provided constructive assessments, comments, and suggestions for improving the physics learning tools based on the ethnoscience-integrated Inquiry-Creative-Process model. The authors also thank the prospective physics teachers who participated in the limited trial and contributed to the data collection process. Appreciation is also extended to the Department of Physics Education, University of Mataram, for its academic support during the development and implementation of this study.

AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Ni Nyoman Sri Putu Verawati	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	
Ahmad Harjono		✓		✓	✓	✓			✓			✓		
Wahyudi		✓		✓			✓	✓		✓		✓	✓	

CONFLICT OF INTEREST STATEMENT
Authors state no conflict of interest.

ETHICAL APPROVAL
The researchers meticulously followed ethical protocols throughout the research process, adhering to the principles outlined in the Declaration of Helsinki.

DATA AVAILABILITY
The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy considerations of research participants.

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