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# Opportunities to Stimulate the Critical Thinking Performance of Preservice Science Teachers Through the Ethno-Inquiry Model in an E-Learning Platform

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**Abstract.** The acquisition of critical thinking (CT) as one of the 21st century skills is categorically crucial. Therefore, the effective training of CT skills in terms of learning activities needs detailed exploration. This study applied the ethno-inquiry model in an e-learning platform and evaluated its impact on the CT skills of preservice science teachers (PSTs). The experimental design employed the randomized pretest-posttest control design involving 62 PSTs as participants, divided equally into an experimental and control group. Participants' CT skills were assessed using essay tests. The tests focused on the CT skills dealing with analysis, inferencing, evaluation, and decision-making indicators. The CT scores were analyzed using parameters of the average pretest-posttest. The learning implementation effects were calculated using a paired *t* test and analysis of covariance (ANCOVA) at the significance level of .05. The findings demonstrated that the CT scores for the experimental group increased from the less critical to the critical level. This result was better than that of the control group. Similarly, the improvement of individual CT performance was better in the experimental group. Based on the results of the analysis, the *t* test and ANCOVA of both groups confirmed that the ethno-inquiry model had a significant effect on the CT skills of participants. The results thus provide convincing evidence of the essential

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roles of the ethno-inquiry model in science learning and it is therefore recommended that the model be implemented in science classes.

**Keywords:** critical thinking skills; e-learning platform; ethno-inquiry model; preservice science teachers

## 1. Introduction

The recent developments of digital technology, the interest in using the internet, and the trend of virtual learning have changed learning systems worldwide, where face-to-face learning is being replaced by an online system (e-learning). It has been predicted that e-learning will be applied massively in all modes of education and learning around the world by 2025 (Palvia et al., 2018). This is a challenge for education stakeholders to prepare the pedagogical model infrastructure with a digital system (Herodotou et al., 2020). At the same time, it presents a good opportunity to continue to support preservice science teachers' (PSTs) achievement of critical thinking (CT) as demanded by 21st century global learning needs (Bilad et al., 2022).

In today's modern education, higher education is increasingly crucial in building CT as a competency and a learning experience that strongly support students' future professional abilities (Erikson & Erikson, 2019). Even developed countries have paid significant attention to this issue, as a strategic effort to make CT skills a core graduate attribute in higher education curricula (Verawati et al., 2019). The implication is that every effort and learning-teaching process in the classroom are oriented towards CT achievement (Bezanilla et al., 2019). However, the current mechanism for CT classroom training is still a problem, especially since lecturers' competence and performance are low in intervening in CT training (Gilmanshina et al., 2021). On the one hand, it is recognized that CT is necessary for students in higher education; however, it is still challenging in relation to teaching and still appears difficult and is thus a topic of debate (Lee et al., 2021).

Previous studies have shown that the CT performance results of PSTs were not so promising. For example, an essay study conducted by Trostek (2020) on 38 PSTs in Sweden showed their poor level of reasoning and analytical skills. These findings are in line with that of Ma and Luo (2021), who found that the CT performance of prospective senior scholars at five Chinese universities was inadequate. The inadequate CT performance was resultant of the limited learning experience and no support of learning activities emphasizing CT (Ma & Luo, 2021). The results of a study on PSTs were not less worrying. The findings of a study by Fitriani et al. (2019) showed that the CT skills of learners were not developing, and it was recommended that a strict plan be followed to overcome the problems. Some educational institutions seem not to rely too much on the achievement of CT skills and place more emphasis on student academic achievement. However, academic achievement is derived from the CT activities, and many studies have reported that CT performance impacts academic achievement (D'Alessio et al., 2019; Ghanizadeh, 2017; Siburian et al., 2019).

Universities can build a culture of CT in students by modernizing the teaching system as such to lead to the achievement of CT (Dekker, 2020). One such method is to apply an innovative learning model based on inquiry activities (Verawati et al., 2021). On the one hand, the integration of local-wisdom values in learning is highly emphasized (Suprapto et al., 2021). What is in question here is the characteristic of a holistic learning process that encourages the formation of a comprehensive mindset by internalizing local and national wisdom. In the context of science teaching, the enculturation of science by internalizing local wisdom is referred to as ethnoscience (Sudarmin et al., 2019).

Inquiry is recognized as a teaching foundation to train students how to think (Arends, 2012), while ethnoscience, which is taught through an investigation or exploration process, has the potential to train CT skills (Ramdani et al., 2021). By integrating ethnoscience and inquiry (ethno-inquiry) as a digitally presented learning model (e-learning), the perfect combination is created that can provide a learning experience for students to support their CT performance. It is important that the ethno-inquiry model within the framework of an e-learning system is developed in learning, which will involve various important factors. First, an innovative and interactive digital learning model is needed that supports learning interactivity to achieve students' CT goals. Second, ethnoscience is a learning characteristic that is expected in today's science teaching, especially in the context of developing regional potential-based learning (local cultural values), as a means of building national competitiveness, and to encourage students' CT. Third, ethno-inquiry can be a learning model that can accommodate the needs of science learning in general, prioritize the knowledge-acquisition process, and specifically train CT through exploration activities on contextual problems.

### 1.1 Research Aim and Hypothesis

This study aimed to implement the ethno-inquiry model in an e-learning platform and then evaluate its impact on the CT skills of PSTs. Based on the research aim, the research hypothesis is that the ethno-inquiry model in the e-learning platform has a statistically significant impact on the CT skills of PSTs when compared to traditional teaching. In addition, the significant impact of the ethno-inquiry model of the e-learning platform leads to its effectiveness in improving the CT skills of PSTs.

### 1.2 Study Context

Cultural diversity and local-wisdom values in Indonesia can be used to create opportunities to impart scientific ways of thinking to students in higher education. One of the expected characteristics stipulated in the Indonesian National Standard for Higher Education is a holistic instructional process to encourage a comprehensive mindset by internalizing local and national wisdom. In the context of science learning, the enculturation of science by internalizing local-wisdom matters is referred to as ethnoscience (Sudarmin et al., 2019). The achievement of the National Standard for Higher Education criteria is supported by the Independent Learning-Independent Campus Program in Indonesia, where one of the instructional objectives is to develop students' talent to be able to think critically. Furthermore, higher education institutions that educate prospective teachers are expected to play a crucial role in supporting the national education standards to be achieved, and the Independent Learning-Independent Campus Program to be applied well. Through a decentralized research mechanism, the Mandalika University of Education has established a leading field of research, namely educational policy and innovation. This was done by developing instructional activities based on regional potential (local cultural values) as a means of building the nation's competitiveness and encouraging students' CT.

The context of the current study is in accordance with the university's leading field of research, so that the context of ethnoscience in ethno-inquiry learning is strongly related to the Indonesian national cultural entity. The participants involved in this study were PSTs from Indonesia. All learning instruments, such as lesson plans and scenarios, teaching materials, students' worksheets, and CT skills tests, were presented in Indonesian to be understood well. The language of instruction was also Indonesian, as this was the participants' mother tongue, so that the ethnoscience context being taught could be understood by participants. Finally, although this study was conducted in the context of Indonesian ethnoscience, it provides an opportunity to be applied in a wider context to encourage other countries to explore ethno-inquiry.

## 2. Literature Review

### 2.1 Critical Thinking Skills

John Dewey as a psychologist has long emphasized CT concepts. He explained that CT is the same as reflective thinking, and that it is known as active thinking, where the individual is persistent and thorough in their consideration of knowledge in terms of the reasons (Dewey, 1910). Active-thinking processes can be contradicted with an illustration of where a learner takes information and ideas of others for granted, does not think deeply, and cannot engage in active-thinking processes (this is called passive thinking). Facione (2020) stated that CT is a detailed elaboration of several characteristics engaging the interpretation and analysis activities. Furthermore, CT involves learners carrying out evaluation tasks, inferencing activities, explanation activities, and self-regulation learning activities. Similarly, Ennis (2011) stated that the concept of CT involves reasoning and reflecting, which focus on deciding what to believe and do. In another definition, Elder and Paul (2012) explained that CT is a way of thinking about any matter or problem. A learner can skillfully improve their thinking by handling the structures inherent in thinking and applying intellectual standards to it. Furthermore, CT refers to analyzing and evaluating activities to think critically with a perspective to enhance the skill itself.

Almost every expert dealing with CT issues has recognized such thinking skills as a fundamental factor. As far as review of the related literature is concerned, we have concluded that CT is extracted from three approaches: philosophical, cognitive psychological, and educational. The philosophical approach emphasizes the qualities and characteristics of a critical thinker. The cognitive psychological approach highlights the real action and behavior performed by a critical learner who should have skills. Lastly, the educational approach directs the thinking process towards higher skills, called higher order thinking (HOT) skills. Without discrediting or ignoring the CT views of certain experts, in the context of the current study, we tended more to adhere to the CT view according to Ennis (2018) and adapting the four leading indicators of CT abilities (analysis, inferencing, evaluation, and decision-making). These four indicators have been elaborated extensively in previous studies (Verawati et al., 2019, 2021; Wahyudi et al., 2018, 2019), because these reflect the view of CT from a philosophical, psychological, and educational approach. In addition, the indicators have reflected aspects of learning required at the higher education level.

**2.2 Inquiry Learning**

In science teaching, inquiry learning is becoming increasingly popular. This can be seen from the developments in teaching and research projects in science that continue to lead to scientific inquiry issues (Pedaste et al., 2015). Since the early 20th century, inquiry learning activities have long been echoed by Dewey, who implied using inquiry activities in learning (Tillmann et al., 2017). However, we argue that scientific inquiry was extracted from the Atkin-Karplus learning cycle popularized in 1962 (Hussain et al., 2011), where within the teaching phase, they presented the steps of inquiry that became the forerunners of inquiry activities.

Sund and Trowbridge (1973) defined inquiry as a teaching method focusing on how learners understand, develop, and apply their new ideas through systematic questions, hypotheses, and experiments involving discovery activities. In the classroom teaching practice, students resemble professional scientists in constructing their knowledge (Keselman, 2003). In inquiry, knowledge is built through the process of discovering causal relationships. It begins with formulating hypotheses and conducting experiments to test them (Pedaste et al., 2012). Compared with other teaching-learning strategies such as direct instruction, inquiry teaching is assumed to produce better learning performance (Alfieri et al., 2011). Others have also stated that inquiry learning or experimentation is better than traditional teaching, which does not invite students to explore (Furtak et al., 2012; Verawati et al., 2022).

Arends (2012) elaborated that inquiry activities are a learning model to teach learners to think. Learning tasks in inquiry learning are oriented towards the contents and processes. Regarding the content, teachers want to direct their learners to gain new insight through investigation activities. The process is oriented towards helping students learn the inquiry activities, especially those dealing with scientific inquiry, and to develop a positive stance towards investigation activities. Professional experts have used many terms to describe inquiry. For instance, Buck et al. (2008) used guided inquiry, open inquiry, structured inquiry, inquiry teaching, inquiry learning, and scientific inquiry. However, the core of all processes involving students in inquiry learning activities are the processes of problem identification and hypothesis formulation, and testing those through experimental activities such as data collection, data analysis, and drawing conclusions based on the hypotheses established (Minner et al., 2010).

## 2.3 Ethnoscience

Ethnoscience, a term originating in the 1960s, has often been defined as a field of inquiry used to identify the conceptual schemes that indigenous peoples use to organize their experiences of the environment (Rist & Dahdouh-Guebas, 2006). The term ethnoscience comes from the word *ethnos* (from Greek), which refers to *nation*, and the word *scientia* (from Latin), which means *knowledge*. Ethnoscience thus means knowledge possessed by a nation, or an ethnic group, or a certain social group.

Sturtevant (1964) defined ethnoscience as a system of knowledge and cognition typical of a given culture. The emphasis is on knowledge systems or devices that are unique to a community (local wisdom), because it is different from the knowledge of other communities. Ethnoscience is developed further to identify material phenomena that are considered important by a society or culture and how these phenomena are organized in their knowledge system. It is then known as indigenous knowledge or indigenous science.

Ethnoscience can be interpreted as a system of knowledge about nature that is owned by a certain indigenous or traditional culture. This knowledge covers aspects of ecology and the interrelationships between humans and nature (Rist & Dahdouh-Guebas, 2006; Zidny et al., 2020). Ethnoscience is sometimes referred to by other names, such as "indigenous science" or "traditional ecological knowledge" (Zidny & Eilks, 2022).

## 2.4 Integration of Ethnoscience and Inquiry (Ethno-Inquiry) in Learning

The process of inquiry in the context of science teaching is inseparable from students' learning experiences in the environment and culture in which they grow and develop. In addition, the expression of scientific thought is a manifestation of the local environment and culture (Fasasi, 2017). The integration of local wisdom and cultural values with scientific principles is called ethnoscience (Sudarmin et al., 2019). Scientific problems can be solved by integrating inquiry processes with ethnoscience concepts. Inquiry is recognized as a teaching foundation to train students how to think critically, while ethnoscience, which is taught through an inquiry process, has the potential to train CT skills (Ramdani et al., 2021). Therefore, it is important to develop a learning model that integrates ethnoscience with inquiry (ethno-inquiry). In the current research context, the ethno-inquiry model is used to support the CT performance of PSTs.

The ethno-inquiry model is defined as a learning model based on integrating scientific inquiry activities with ethnoscience. As such, the existing ethnoscience and the indigenous knowledge of the community are investigated through scientific inquiry activities. One form of integration involves the process of experimentation with adequate analytical methods in solving ethnoscience problems that exist in society.

In principle, PSTs' learning experiences are utilized to carry out an in-depth exploration towards local cultural values related to science, and the problems are solved using scientific principles. This process becomes a CT drilling process for students. An example of the CT drilling process in the ethno-inquiry learning model is when students are required to be skilled in reflecting on scientific phenomena that become cultural traditions and local wisdom, identify specific ethnoscience problems contained therein, and solve ethnoscience problems through experimentation or other analysis methods that support ethnoscience problem-solving. These then become important aspects of how student CT skills can be developed through the ethno-inquiry model. The learning phases of the ethno-inquiry model to support the achievement of CT skills are presented in Table 1.

**Table 1. Learning phases of the ethno-inquiry model**

| Learning phase | Description of learning process |
|---|---|
| 1. Ethno-orientation | • Prepare students to learn and introduce ethnoscience concepts. |
| 2. Ethno-reflection | • Invite students to reflect on scientific phenomena that have become cultural traditions and local wisdom. |
| 3. Ethno-authentic problem | • In-depth discussion of ethnoscience phenomena based on students' prior experiences, and identifying specific problems related to learning materials. |
| 4. Ethno-problem-solving | • Solve ethnoscience problems: This can be done through experimentation or analytical methods that support problem-solving. |
| 5. Ethno-explanation | • Formulate scientific explanations of ethnoscience phenomena based on ethnoscience problems. |

The ethno-inquiry model is presented in an e-learning platform. This is in line with the growth of digitalization systems, interest in using the internet, and trend of virtual learning (online) which have replaced face-to-face learning. Therefore, an innovative and interactive digital learning model is needed that supports interactive learning to attain students' CT goals. The results of previous studies showed that digital learning (e-learning) plays an important role in improving students' CT performance (Chen & Wu, 2021). The implementation of a well-designed online learning system can create an active, collaborative learning environment; motivate students to be actively involved in the learning process; and train students' CT skills (Ebadi & Rahimi, 2018).

## 3. Methodology

### 3.1 Research Design

A true experimental study was conducted with the randomized pretest-posttest control design (Fraenkel et al., 2012). The design adopted was as follows:

| | | | | |
|---|---|---|---|---|
| Experimental group | R | $O_1$ | $X_1$ | $O_2$ |
| Control group | R | $O_1$ | $X_2$ | $O_2$ |

The experimental ($X_1$) and control ($X_2$) groups were designated, and the measurements were done twice, first as a pretest and secondly as a posttest. Randomization was carried out to form the experimental and control groups. Observations were made at the same time levels for both groups. The experimental group ($X_1$) was given a learning method with the ethno-inquiry model in the e-learning platform, while the control group ($X_2$) was subjected to an expository learning method (traditional teaching).

**3.2 Participants**

The participants of this study were PSTs in the first semester at Mandalika University of Education. In all, 62 PSTs formed the research sample, which was equally divided into 31 PSTs for the experimental group and 31 PSTs for the control group. The experimental and control groups were selected using simple random sampling. Participants were between 19 and 20 years of age, with the sample being relatively balanced as to gender (male and female participants).

Within the scope of the research, for the involvement of humans as research participants, research permits were obtained from the Institute for Research and Community Service at the Mandalika University of Education (with number 2022/104).

**3.3 Research Procedures**

The research procedure was in accordance with the research design adopted in this study. First, experimental and control groups were formed based on randomization of the sample. Next, the CT skills of the groups were observed (as the pretest) in both groups using a CT skills test instrument. Thereafter, both groups underwent the learning implementation, with the experimental group taught using the ethno-inquiry learning model of the e-learning platform, while the control group was subjected to expository learning (traditional teaching). After the learning implementation was completed for each group, the CT skills were observed in both (as the posttest). The results of the CT skills between pretest and posttest were then analyzed and concluded according to the objectives and hypotheses in this study. The implementations for both groups were carried out as far as possible to avoid threats of internal and external validity. Each sample group was formed through randomization so that the two were relatively balanced. The pretest and posttest were conducted at the same time for both groups, the learning process was scheduled at the same time, the materials were administered at the same, but the learning models used were different. In addition, the tutors who taught in each group had equally adequate knowledge and experience in the context of the applied model.

**3.4 Research Instruments**

The classroom learning utilized some learning tools (LTs), including lesson plans and scenarios, teaching materials, students' worksheets, and CT skills test instruments. The CT skills test instruments were in the form of essay questions consisting of eight questions to accommodate the CT skills indicators in the aspects of analysis, inferencing, evaluation, and decision-making. Before the LTs were implemented, two validators assessed their validity. The validators were selected based on specific criteria. They had to: (a) be professionals involved in science learning; (b) have at least a doctorate in science education; and (c) have three years of experience in instructional design. The content and construct validity were evaluated on all aspects of the LTs. The LTs were declared as having a good degree of validity if the minimum score was valid. If the score attained was low, the validity was revised (Fitriani et al., 2022). The reliability of the LTs was determined according to the assessment by the validators, using a percentage of agreement (Emmer & Millett, 1970). Finally, referring to the validation results, the LTs were declared valid and reliable, and could thus be used to support the implementation of the ethno-inquiry model.

Table 2 presents the scoring rubric used for each item of the test instrument (essay test). The test instrument was employed to assess the CT skills of participants with analysis, inferencing, evaluation, and decision-making as skill indicators. Scoring was adopted from the Ennis-Weir Critical Thinking Essay Test, with five scoring scales (-1, 0, +1, +2, and +3) (Prayogi et al., 2018). Each CT indicator contained two test items, so the total number of test instrument items was eight.

**Table 2. The scoring rubric for testing CT skills in the test instruments**

| Score | Descriptor |
|---|---|
| -1 | The answer was incorrect, with incorrect arguments not supported by facts, concepts, and laws. |
| 0 | No answer was provided. |
| +1 | The answer was correct, but each CT indicator was not supported by strong arguments, facts, concepts, and laws. |
| +2 | The answer was correct, and each CT indicator was sufficiently supported by arguments, facts, concepts, and laws. |
| +3 | The answer was correct, and a strong argument supported each CT indicator with facts, concepts, and laws. |

### 3.5 Data Analysis

Data on participants' CT skills were analyzed descriptively and statistically. Descriptive analysis of CT skills scores was conducted for both the experimental and the control groups on each pretest, posttest, and n-gain. Analysis was done on each CT indicator and on the CT performance of individual participants (CTi and CTs, respectively). Each scoring method was guided by the rubric shown in Table 2, while the category of CT skills for each indicator was according to the score interval shown in Table 3. The score interval of Verawati et al. (2021) was used, where Xi is the ideal average and Sdi is the ideal standard deviation, both of which depend on the maximum and minimum scores. The CT skills for each indicator (CTi) were scored from -1 to +3. Thus, the range of the CT score of each individual (CTs) was -8 to +24 (based on the eight test instrument items). The increase of CT skills scores between the pretest and posttest of each sample group was evaluated through n-gain analysis (Hake, 1999).

**Table 3. Criteria of CT skills scoring**

| Interval scores | Interval scores of CTi | Interval scores of CTs | Criterion |
|---|---|---|---|
| $CT > X_i + 1.8\ Sdi$ | $CTi > 2.20$ | $CTs > 17.6$ | Very critical |
| $X_i + 0.6\ Sdi < CT \leq X_i + 1.8\ Sdi$ | $1.40 < CTi \leq 2.20$ | $11.2 < CTs \leq 17.6$ | Critical |
| $X_i - 0.6\ Sdi < CT \leq X_i + 0.6\ Sdi$ | $0.60 < CTi \leq 1.40$ | $4.8 < CTs \leq 11.2$ | Critical enough |
| $X_i - 1.8\ Sdi < CT \leq X_i - 0.6\ Sdi$ | $-0.20 < CTi \leq 0.60$ | $-1.6 < CTs \leq 4.8$ | Less critical |
| $CT \leq X_i - 1.8\ Sdi$ | $CTi \leq -0.20$ | $CTs \leq -1.6$ | Not critical |

*Note: $X_i$ = ½ (max score + min score); Sdi = 1/6 (max score - min score)*

The measurements of CT skills were based on the analysis parameters of the mean scores of the pretest, posttest, and n-gain. Furthermore, statistical analysis was used to evaluate the differences in the CT scores between groups. This relates to the research hypothesis being tested, namely that the ethno-inquiry model in the e-learning platform has a statistically significant impact on the CT skills of PSTs when compared to traditional teaching. Hypothesis testing was performed statistically using paired *t* test analysis and analysis of covariance (ANCOVA), which was applied at a significance level of .05. Prior to this test, each group of data was tested for normality using the Shapiro-Wilk test at a significance level of .05. All statistical analyses were done using Statistical Package for the Social Sciences (SPSS) 25.0 software.

## 4. Results

The CT skills data of the participants for each indicator (CTi) are summarized in Table 4. (Data of the individual CT performances (CTs) are presented in Table 5.) The data for both the experimental and the control group are represented by the average pretest, posttest, and n-gain scores.

**Table 4. CTi results represented by the mean scores of the pretest, posttest, and n-gain**

| Group | Score | CT skills indicators (mean group values) | | | |
|---|---|---|---|---|---|
| | | Analysis | Inferencing | Evaluation | Dec.-making |
| Experimental (n = 31) | Pretest | 0.16 | 0.08 | 0.11 | 0.18 |
| | Posttest | 2.08 | 1.98 | 2.13 | 2.11 |
| | n-gain | 0.50 (Moderate) | 0.48 (Moderate) | 0.52 (Moderate) | 0.51 (Moderate) |
| Control (n = 31) | Pretest | 0.35 | 0.19 | 0.29 | 0.40 |
| | Posttest | 0.90 | 0.79 | 0.63 | 0.82 |
| | n-gain | 0.15 (Low) | 0.16 (Low) | 0.09 (Low) | 0.12 (Low) |

Table 4 shows the results of each indicator of the CT skills test for both the experimental and the control group based on the analysis parameters of the mean scores of the pretest, posttest, and n-gain. It shows that all the participants' CT skills (pretest) were at the less critical level for all indicators ($-0.20 < CTi \leq 0.60$) (see the criteria of CT skills scoring in Table 3). For the experimental group, the pretest results on inferencing received the lowest CTi score (0.08), followed by the evaluation (0.11), analysis (0.16), and decision-making indicators (0.18). Likewise, for the control group, the inferencing indicator also received the lowest CTi score (0.19), followed by the evaluation (0.29), analysis (0.35), and decision-making indicators (0.40). A visualization of the CT skills data of the participants for each CTi is presented in Figure 1.

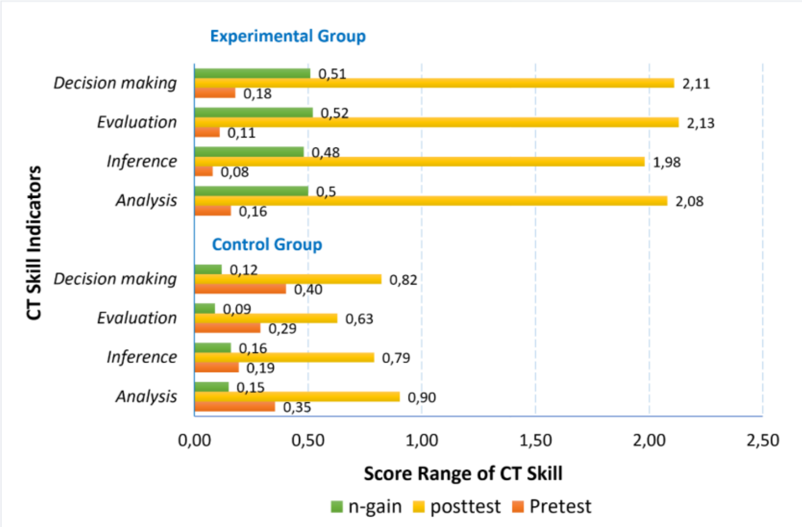


**Figure 1. The CT skills data visualization of the participants for each CTi**

Implementation of the ethno-inquiry model in the e-learning platform on participants in the experimental group impacted the posttest results of each indicator. This can be seen from the posttest results of the experimental group (see Table 4 and Figure 1), where the average CTi score was at the critical level (1.40 < CTi ≤ 2.20). Different results were yielded for the control group (traditional teaching), where the average CTi score was at the critical enough level (0.60 < CTi ≤1.40). Data of the individual CT performances (CTs) are presented in Table 5.

**Table 5. CTs results represented by the mean scores of the pretest, posttest, and n-gain**

| Group | Individual CT performances (CTs) | | | | n-gain | Criterion |
|---|---|---|---|---|---|---|
| | Pretest | Criterion | Posttest | Criterion | | |
| Experimental (n = 31) | 1.06 | Less critical | 16.61 | Critical | 0.67 | Moderate |
| Control (n = 31) | 2.48 | Less critical | 6.29 | Quite critical | 0.17 | Low |

Table 5 shows the results of participants' individual CT performance (CTs) based on the analysis parameters of the mean scores of the pretest, posttest, and n-gain. Regarding the pretest, the groups had CTs scores of 1.06 and 2.48, respectively, both under the less critical level (-1.6 < CTs ≤ 4.8). In the posttest results, the experimental group was at the critical level, with a CTs score of 16.61 (11.2 < CTs ≤ 17.6), while the control group was at the critical enough level, with a CTs score of 6.29 (4.8< CTs ≤ 11.2). The difference in n-gain between the two sample groups based on individual CT performance (CTs) is presented in Figure 2.

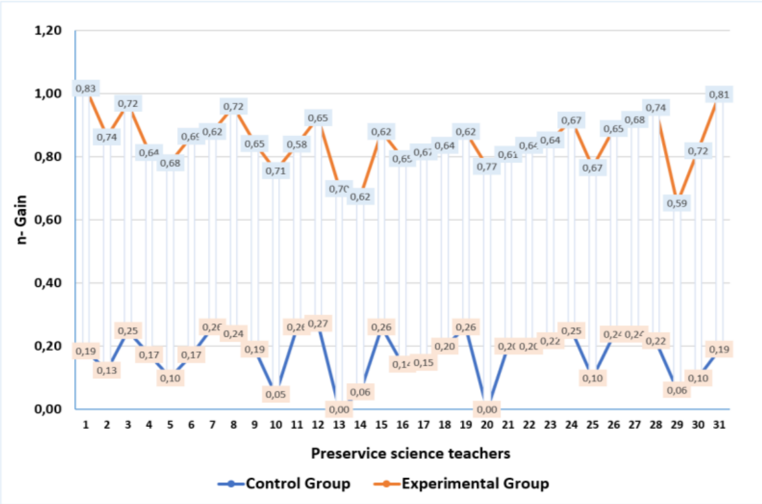


**Figure 2. The difference in n-gain between the two sample groups based on individual CT performances (CTs)**

The n-gain of the two groups differed significantly. The experimental group was at the moderate level (n-gain = 0.67), while the control group was at the low level (n-gain = 0.17). The difference in CT skills scores of the participants between groups was tested statistically. The average score, standard deviation, and the results of the data normality test for each group are displayed in Table 6. For the normality test, the Shapiro-Wilk technique was used, and the normality test results were used as a reference in the parametric statistical testing.

**Table 6. The average score, standard deviation, and results of the data normality test for each group (*p* > .05)**

| Group | Test | n | Mean | SD | Sig. | Normality |
|---|---|---|---|---|---|---|
| Experimental | Pretest | 31 | 1.064 | 1.807 | 0.200 | Normal distribution |
| | Posttest | 31 | 16.612 | | | |
| Control | Pretest | 31 | 2.484 | 1.794 | 0.200 | Normal distribution |
| | Posttest | 31 | 6.290 | | | |

The normality assumption analysis was met, so we applied the parametric statistical analysis (paired *t* test) for each group, the results of which are presented in Table 7.

**Table 7. The average score, standard deviation, and results of the paired *t* test of participants' CTs scores (*p* < .05)**

| Group | | n | Mean | SD | df | *t* | Sig. |
|---|---|---|---|---|---|---|---|
| Experimental | Pretest | 31 | 1.064 | 1.86074 | 30 | -35.980 | 0.000 |
| | Posttest | 31 | 16.612 | 1.14535 | | | |
| Control | Pretest | 31 | 2.484 | 2.14275 | 30 | -11.230 | 0.000 |
| | Posttest | 31 | 6.290 | 1.75487 | | | |

The paired *t* test for both groups yielded a *p* value < .05 (see Table 7), demonstrating significant differences between the CT skills of participants before and after implementation in each group. It also confirmed the findings in Table 5, where CT skills scores improved in the two sample groups from less critical to critical (experimental group) and from less critical to critical enough (control group). The CT skills results of the ANCOVA test are presented in Table 8. The ANCOVA test was conducted to analyze the effect of the learning implementation (ethno-inquiry model in the e-learning platform) on the CT skills of the participants.

**Table 8. The ANCOVA results regarding the CTs of participants ($p < .05$)**

| Source | Sum of sqr. | df | Mean sqr. | F | Sig. |
|---|---|---|---|---|---|
| Corrected model | 1660.531 | 2 | 830.266 | 398.829 | 0.000 |
| Intercept | 4233.910 | 1 | 4233.910 | 2033.815 | 0.000 |
| Pretest | 8.918 | 1 | 8.918 | 4.284 | 0.043 |
| Group | 1540.884 | 1 | 1540.884 | 740.184 | 0.000 |
| Error | 122.824 | 59 | 2.082 | | |
| Total | 9914.000 | 62 | | | |
| Corrected total | 1783.355 | 61 | | | |

The results in Table 8 show a significant difference between each group in terms of CT skills of participants in the posttest after the implementation of the learning (ethno-inquiry model in the e-learning platform), with $F_{group}$ = 740.184 ($p < .05$). The covariate variable (pretest) had at least had an effect on participants' CT skills, with $F_{pretest}$ = 4.284 ($p < .05$). The findings indicate that the ethno-inquiry model experienced by the experimental group was effective in improving the CT skills of participants when compared to the traditional teaching experienced by the control group.

## 5. Discussion

Table 4 shows the results of each CT skills indicator for both the experimental and control group based on the analysis parameters of the mean scores of the pretest, posttest, and n-gain. Results showed that all the participants' CT skills (pretest) were at the less critical level for all indicators ($-0.20 < CTi \leq 0.60$). For the experimental group, the pretest results on the inferencing indicator received the lowest CTi score, followed by the evaluation, analysis, and decision-making indicators. Likewise, for the control group, the inferencing indicator also received the lowest CTi score, followed by the evaluation, analysis, and decision-making indicators. The low level of CT skills by PSTs was also reported in other studies (Prayogi et al., 2018), which identified aspects of analysis, inferencing, evaluation, and decision-making indicators that were uncritical during the pretest. This poor situation is most likely due to the previous learning experiences of PSTs, where they were not trained to think critically.

The implementation of the ethno-inquiry model in the e-learning platform on participants (experimental group) impacted the posttest results of each indicator. This can be seen from the posttest results of the experimental group (see Table 4), where the average CTi score was at the critical level ($1.40 < CTi \leq 2.20$). Different results were shown for the control group (traditional teaching), where the average CTi score was at the critical enough level ($0.60 < CTi \leq 1.40$). These results respond to the problem in the findings of previous studies that PSTs face difficulties practicing CT aspects such as inferencing (Qing et al., 2010) and evaluation (Miri et al., 2007) by applying inquiry learning.

This study demonstrated empirical evidence that the ethno-inquiry model in the e-learning platform can improve aspects of the CT skills of PSTs. Descriptive analysis of the parameter improvement of each CTi score (n-gain) showed different results for the two groups (experimental and control). The n-gain score of the experimental group was moderate (n-gain = 0.3–0.7), while in the control group it was low (n-gain < 0.3). This finding refutes previous claims (Uiterwijk-Luijk et al., 2019) that learners' CT habits were not affiliated with the teacher's inquiry approach. The finding of our study implies that the improvement of CT skills categorically occurred in accordance with the implementation of the ethno-inquiry model in the e-learning platform.

Participants' individual CT performance was measured based on the analysis parameters of the scores of the pretest, posttest, and n-gain. The results in Table 5 for the pretest showed that the groups had CTs scores of 1.06 and 2.48, respectively, both under the less critical level (-1.6 < CTs ≤ 4.8). For the posttest, the experimental group was at the critical level, with a CTs score of 16.61 (11.2 < CTs ≤ 17.6), while the control group was at the critical enough level, with a CTs score of 6.29 (4.8 < CTs ≤ 11.2). The n-gain score of the two groups differed significantly. The experimental group was at the moderate level (n-gain = 0.67), while the control group was at the low level (n-gain = 0.17). The difference in CT skills scores of the participants between groups was tested statistically. Table 6 shows the average score, standard deviation, and the results of the normality test of the data for each group. The normality test results showed that the sample group data were normally distributed ($p > .05$). The normality test results become a reference in the statistical (parametric) testing, as shown in Tables 7 and 8. The paired *t* test for both groups yielded a *p* value < .05 (Table 7), demonstrating significant differences between the CT skills of participants in both groups before and after the learning implementation. It also confirmed the findings in Table 5, where CT skills scores improved in the two sample groups from less critical to critical (experimental group) and from less critical to critical enough (control group).

Comparisons between the two groups were analyzed using ANCOVA (Table 8). A significant difference was shown between each group in terms of the CT skills of participants in the posttest after the implementation of the learning (ethno-inquiry model in the e-learning platform), with $F_{group} = 740.184$ ($p < .05$). The covariate variable (pretest) had at least had an effect on participants' CT skills, with $F_{pretest} = 4.284$ ($p < .05$). The findings indicated that the ethno-inquiry model experienced by the experimental group was effective in improving the CT skills of participants when compared to the traditional teaching experienced by the control group.

Through inquiry, learners' CT skills have been trained through exploration (Ernita et al., 2021), while through ethno-inquiry learning, PSTs have reflected on the rules of science in everyday life in accordance with cultural entities and local wisdom. This practice of reflection is important as a process of cognitive regulation (Asy'ari & Da Rosa, 2022), where PSTs have the experience of learning how they self-evaluate each process and the way they think (Choy et al., 2017). The self-assessment process carried out continuously has an impact on increasing the CT skills of PSTs (Verawati et al., 2021). In addition to training CT skills, other studies have also reported that the practice of reflection impacts more meaningful deep learning (Griggs et al., 2018). These findings are relevant to previous studies (Colomer et al., 2020), suggesting that reflection could encourage new reasoned action plans to make decisions (decision-making) correctly. It is also carefully understood that reasoned action in decision-making is the fundamental essence of CT (Ennis, 2018).

The learning process is characterized by cognitive contemplation, managing and monitoring the process through sharpening skills and actively experimenting (Cañabate et al., 2019; Lozano et al., 2017), which can be done through scientific inquiry. The learning framework in the ethno-inquiry model has emphasized the reflective process (ethno-reflection). In some conditions, the process of ethnoscience reflection is seen as an anomalous phenomenon on actual problems that become cultural traditions. This becomes a reflection-pedagogic intervention space needed to achieve CT. The presentation of ethnoscience that emphasizes authentic problems is a process where PSTs can reflect deeply on existing information based on previous knowledge. In inquiry learning, this is found to be the best process of reflection (Kahan, 2013). Previous study reports have shown that presenting authentic problems can encourage students and serve as bridge to hone their CT skills (Akmam et al., 2018) and creativity in problem-solving (de Oliveira Biazus & Mahtari, 2022).

Ethnoscience problem-solving is done through experimentation. In experimental activities, PSTs monitor the process at the data collection steps; they identify each step and errors in the experimental procedures carried out. It is categorized as a reflection on the control of learning experiences done by self-knowledge through connecting real experiences (Colomer et al., 2018). Performance evaluation is carried out carefully on the learning process, specifically on how PSTs reflect experimental findings based on the hypotheses built, examine the learning process that had been carried out, and identify errors for further improvement. This process supports the development of their CT skills (Procter, 2020). Finally, the ethnoscience problem-solving steps that have been carried out through experiments have proven effective in training the CT skills of PSTs.

## 6. Conclusion

The implementation of the ethno-inquiry model in the e-learning platform was evaluated and showed a convincing impact on improving the CT skills of the participating PSTs. The CTi performance for the experimental group (ethno-inquiry model in the e-learning platform) increased from less critical ($0.2 < CTi \leq 0.6$) to critical ($1.4 < CTi \leq 2.2$), better than that of the control group (traditional teaching), which only increased from less critical to critical enough ($0.6 < CTi \leq 1.4$). Similarly, the CTs performance was better for the experimental group, increasing from 1.06 to 16.6 and with a moderate n-gain of 0.67, than for the control group, with an increase from 2.48 to 6.29 and with a low n-gain of 0.17. Based on the results of analysis, the *t* test and ANCOVA of both groups confirmed that the ethno-inquiry model had a significant effect on participants' CT skills. This means that the results provide convincing evidence on the essential role of the ethno-inquiry model in science learning and it is recommended as such that the model be implemented in science classes.

The implication of the findings is that the ethno-inquiry learning model can be applied in regular classroom learning to stimulate the CT performance of PSTs. This should be done with the support of an adequate learning environment, broad understanding of learning instructors related to ethnoscience contexts, and an understanding of the ethno-inquiry model itself. A limitation of this research is that CT stimulation does not include aspects of CT disposition. An important recommendation for future research is thus to assess the impact of applying the ethno-inquiry learning model to CT dispositions.

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