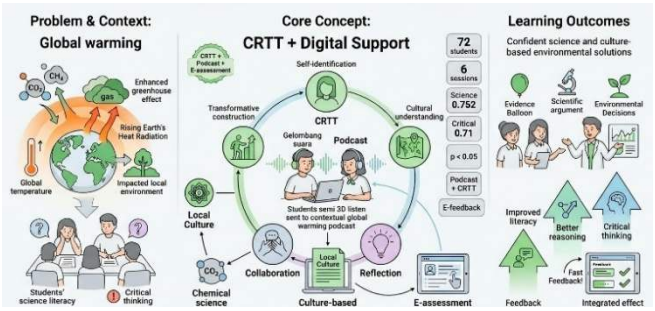
***JKPK (JURNAL KIMIA DAN PENDIDIKAN KIMIA)**, Vol. 11, No. 1, 2026* *pp. 184-204*
Chemistry Education Study Program, Universitas Sebelas Maret *ISSN 2503-4146*
https://jurnal.uns.ac.id/jkpk *ISSN 2503-4154 (online)*

Application of Culturally Responsive Transformative Teaching (CRTT) Model Assisted by Podcast and E-Assessment to Improve Students Science Literacy and Critical Thinking

Hanika Diba Rahmawati[1], Sri Yamtinah[1*], Hayuni Retno Widarti[2], Antuni Wiyarsih[3], Ari Syahidul Shidiq[1]

[1]Chemistry Education Study Program, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Surakarta, Indonesia
[2]Chemistry Education Study Program, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia
[3]Chemistry Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

ABSTRACT



This study investigates the implementation of the Culturally Responsive Transformative Teaching (CRTT) model integrated with podcast media, culture-based worksheets (LKPD), and e-assessment in relation to students' science literacy and critical thinking skills. A quasi experimental design with a non-equivalent group structure was employed, involving 72 students from two classes, consisting of one experimental group receiving the integrated intervention and one comparison group experiencing conventional instruction. Podcast media were used to deliver contextual and narrative-based content on global warming, while CRTT stages cultural understanding, collaboration, and transformative construction guided classroom activities. Student outcomes were measured using science literacy and critical thinking tests administered through e-assessment. Data were analyzed using the Kruskal–Wallis test to compare differences between groups for each dependent variable. The results indicated statistically significant differences ($p < 0.05$) in both science literacy and critical thinking scores between the experimental and comparison groups. However, given that the intervention simultaneously combined multiple components (CRTT model, podcast media, culture-based LKPD, and e-assessment), the observed effects cannot be attributed to a single instructional element in isolation.Overall, the findings suggest that the integrated approach is associated with improved student outcomes, although further research using more controlled designs is needed to disentangle the specific contribution of each component.

Keywords: *Culturally Responsive Transformative Teaching (CRTT); educational podcast; e-assessment; science literacy; critical thinking skills*

**Corresponding Author: jengtina@staff.uns.ac.id*
How to cite: H.D. Rahmawati, S. Yamtinah, H.R. Widarti, A. Wiyarsih, and A.S. Shidiq, "Application of Culturally Responsive Transformative Teaching (CRTT) Model Assisted by Podcast and E-Assessment to Improve Students Science Literacy and Critical Thinking," *Jurnal Kimia dan Pendidikan Kimia (JKPK)*, vol. 11, no. 1, pp.184-204, 2026. [Online]. Available: https://doi.org/10.20961/jkpk.v11i1.116813
Received: 2026-03-18 *Accepted: 2026-04-28* *Published: 2026-04-30*

INTRODUCTION

The rapid development of science and technology in the 21st century demands that students master higher-order thinking skills, including critical thinking, creativity, collaboration, and communication, as emphasized in Permendikbud No. 64 of 2013 [1]. However, chemistry learning practices in schools remain predominantly teacher-centered, relying heavily on lecture-based instruction that limits opportunities for students to actively construct conceptual

understanding [2]. This issue is particularly critical in chemistry due to the abstract and complex nature of its concepts, which often hinders students from connecting scientific knowledge with real-world phenomena [3].

This condition is reflected in the low level of students' science literacy in Indonesia. Results from PISA 2022 indicate that Indonesian students achieved an average score of 383 in science literacy, significantly below the OECD average [4]. At the secondary school level, similar trends are observed, with studies reporting science literacy achievement at only moderate levels. Science literacy is closely linked to critical thinking, as students must analyze, evaluate, and apply scientific knowledge to solve contextual problems [5]. Empirical studies in science education consistently show that critical thinking is a strong predictor of science literacy performance [6]. Therefore, improving both science literacy and critical thinking is essential and should be positioned as central learning outcomes in chemistry education.

In the context of chemistry learning, global warming is not merely a socioscientific issue but also a topic that is deeply rooted in core chemical concepts, such as gas laws, molecular interactions, infrared radiation absorption, and the role of greenhouse gases like CO_2 and CH_4. Understanding global warming requires students to integrate macroscopic environmental phenomena with submicroscopic chemical processes and symbolic representations. However, prior studies indicate that students often struggle to explain the greenhouse effect scientifically and to relate chemical principles to environmental issues [7]. This highlights a gap between conceptual understanding and the ability to apply chemistry knowledge in meaningful contexts, reinforcing the need for instructional approaches that bridge this disconnect.

To address these challenges, an instructional approach is needed that explicitly connects students' cultural backgrounds with transformative learning processes. Culturally Responsive Transformative Teaching (CRTT) differs from general contextual or transformative approaches by systematically integrating cultural identity exploration with critical reflection and social action. Models Culturally Responsive Transformative Teaching (CRTT) is present as an approach that combines transformative learning and cultural integration in learning. This model consists of five stages, namely Self-identification, Cultural Understanding, Collaboration, Critical reflections, and Transformative construction, which aims to encourage students to understand cultural identity, build knowledge collaboratively, and develop critical awareness [8].

In this study, CRTT is further strengthened through the integration of digital media and assessment tools to enhance its instructional effectiveness. The use of podcast media allows flexible, contextual, and student-centered learning experiences, while e-assessment provides immediate feedback and supports continuous evaluation of higher-order thinking skills [9]. Thus, this study does not only examine CRTT as a pedagogical model, but also investigates the

added value of combining CRTT with digital learning media and assessment systems.

This gap is also evident in the local context. Observations indicate that students' scientific literacy and critical thinking skills remain low, particularly on global warming. Students tend to memorize concepts without understanding their relevance to environmental issues or cultural contexts. Furthermore, the use of technology-based learning media, such as podcasts, and digital assessment tools has not been optimally implemented. This demonstrates a mismatch between the demands of 21st-century learning and actual classroom practices, reinforcing the need for an integrated learning approach.

Research conducted by Aisah shows that the integration of educational podcast-based learning media can improve students' science literacy, as seen from a significant increase in science literacy scores after the use of podcasts in learning in schools [10]. In addition, other research found that the development of educational podcast-assisted learning media also contributed to the improvement of students' critical thinking skills, especially when combined with a learning approach that focused on the thinking process and problem-solving [11]. Research shows that the use of podcast media as a learning tool can significantly improve the learning experience in various learning contexts [12].

In addition, the development of *Digital e-Assessment* It has also proven to be effective in improving students' understanding of concepts through technology-based evaluations [13]. Although previous studies have demonstrated that podcast-based learning can improve science literacy and that digital e-assessment can enhance conceptual understanding and evaluation processes [24], these approaches have generally been implemented separately. Likewise, research on CRTT has not yet explored its integration with digital learning media and assessment systems within a unified instructional design. Therefore, a clear research gap exists regarding the effectiveness of combining CRTT, podcast media, and e-assessment in improving both science literacy and critical thinking, particularly in chemistry learning.

Based on this gap, the novelty of this study lies in the development and empirical testing of an integrated instructional approach that combines Culturally Responsive Transformative Teaching (CRTT), podcast-based learning, and e-assessment within the context of global warming in chemistry education. This study not only examines CRTT as a pedagogical model but also extends its application by embedding digital learning media and assessment tools to support higher-order thinking. Theoretically, this integration bridges socio-cultural learning theory, constructivist learning, and technology-enhanced assessment. Practically, it offers a comprehensive model that aligns with the demands of 21st-century chemistry education.

Furthermore, the effectiveness of integrating technology within the CRTT model is highly dependent on the synergy between pedagogical design and digital literacy. The use of digital media, such as podcasts, serves not only as a delivery mechanism but as a cognitive tool to deconstruct abstract chemical concepts into

narratives that resonate with a student's lived experience [25]. Recent studies emphasize that technology-enhanced science education is most effective when the instructional design facilitates social interaction and critical reflection, allowing students to bridge the gap between digital engagement and conceptual mastery [26]. This reinforces the role of e-assessment as an integral part of the cognitive transformation process rather than a mere end-of-unit measurement.

The urgency of strengthening science literacy and critical thinking is also paramount within the context of vocational and technical education. In this domain, students must harmonize practical technical skills with a robust understanding of scientific principles to navigate an increasingly green economy. Integrating the CRTT model into vocational curricula allows students to connect their technical competencies with social responsibility and environmental stewardship [27]. This approach aligns with global trends that position science education as the foundation for sustainable innovation, where a deep understanding of molecular interactions in greenhouse gases becomes essential for developing future-proof technological solutions [28]. Furthermore, technology-enhanced and interactive learning environments have been shown to support the development of students' critical thinking through structured questioning and reflective discussion processes [29].

Accordingly, this study aims to investigate whether the integrated implementation of CRTT, podcast media, and e-assessment can improve students' science literacy and critical thinking skills. These two outcomes are selected because they represent key competencies in understanding and applying chemistry concepts in real-world contexts. Specifically, this study addresses the following research questions: (1) Does the implementation of CRTT-based learning integrated with podcasts and e-assessment significantly improve students' science literacy? (2) Does it significantly enhance students' critical thinking skills? By clarifying the pedagogical mechanism and integrating cultural, cognitive, and technological dimensions, this study contributes to providing a more comprehensive and innovative learning model in chemistry education.

METHODS

1. Research Design

This study employed a quantitative approach using a quasi-experimental method with a pretest–posttest control group design. This design was used because the study was conducted in a natural school setting, where individual random assignment was not practically feasible. Existing classroom groups were therefore used, while baseline comparability was ensured through a homogeneity test.

The sampling procedure involved the random selection of intact classes. Eleven available classes were first tested for homogeneity using one-way ANOVA based on students' prior chemistry scores. Classes with no significant differences ($p > 0.05$) were considered homogeneous. Two homogeneous classes were then randomly selected, with one assigned as the experimental group and the other as the control group.

The experimental group received instruction using the Culturally Responsive Transformative Teaching (CRTT) model assisted by podcast media, whereas the control group received instruction through the discovery learning model commonly implemented in the school. Both groups were taught by the same teacher, with comparable learning objectives, content coverage, instructional duration, and assessment procedures (Table 1).

Implementation fidelity was maintained through standardized lesson plans, observation sheets, and periodic monitoring during the teaching process. Both groups completed a pretest before the intervention to measure initial science literacy and critical thinking abilities, followed by a posttest after the intervention to examine changes in these variables. This study acknowledges that the experimental treatment combined CRTT and podcast media; therefore, the observed effects represent the influence of the integrated instructional package rather than the independent effect of each component.

Table 1. Pretest Design Posttest Control Group Design

Groups	Pretest	Treatment	Post -test
Controls	O1	K1	O3
Experiments	O2	X1	O4

K1 : Learning with *the discovery learning model of* package book media (control group)
X1 : Learning with the Culturally Responsive Transformative Teaching model assisted by podcast media (experimental group)
O1 : Pre test control group
O2 : Pre-test experimental group O3 : Post-test control group
O4: Post-test experimental group

2. Participants

Participants in this study were Grade X students at a public senior high school in Boyolali Regency for the 2025/2026 academic year. The population consisted of 11 classes. The sample was selected using cluster random sampling after homogeneity testing based on students' daily chemistry test scores.

The final sample comprised 72 students, with 36 students in the experimental class and 36 students in the control class, reflecting intact classroom structures in a quasi-experimental design. The participants were generally aged between 15–16 years. The gender distribution across both classes was relatively balanced, and all students had comparable prior exposure to basic chemistry concepts as part of the same national curriculum.

Both classes were taught under similar school conditions, including the same academic schedule, learning facilities, and curriculum standards. In addition, both groups were instructed by the same teacher to ensure consistency in teaching style and classroom management. No substantial classroom-level differences were identified prior to the intervention, aside from the treatment applied in the experimental group.

The use of intact classes was intended to maintain ecological validity, as it reflects real classroom settings. To minimize threats to internal validity, several controls were implemented, including homogeneity testing prior to sampling, the use of equivalent learning materials, consistent instructional time, and standardized assessment instruments across both groups. However,

the lack of individual randomization remains a limitation inherent in quasi-experimental research.

3. Procedure

a. Preparation Stage

At this stage, the researchers developed all instructional components, including lesson plans, podcast media, culture-based LKPD, and e-assessment instruments. The research instruments for measuring science literacy and critical thinking were constructed based on validated indicators and tested on non-sample students to ensure validity and reliability.

b. Implementation Stage

The intervention was implemented over six learning sessions, with each session lasting 90 minutes. Both the experimental and control classes studied the same topic, namely global warming, and were taught by the same teacher to minimize teacher-related variability. The two groups also used the same learning objectives, content coverage, and time allocation. The main difference between the groups was the instructional approach and learning media used during the learning process. Before the treatment was implemented, both classes were given a pretest to measure students' initial science literacy and critical thinking skills.

The experimental class was taught using the Culturally Responsive Transformative Teaching (CRTT) model integrated with podcast media, culture-based LKPD, and an e-assessment platform. The podcast on global warming, presented in Figure 1, was developed by the researchers as a contextual stimulus containing real-life environmental issues connected to local cultural practices. This podcast was mainly used at the beginning of each session to introduce contextual problems, attract students' attention, and encourage them to relate global warming issues to their own cultural experiences.

Learning activities in the experimental class followed the syntax of the CRTT model. During the self-identification phase, students listened to the global warming podcast and identified environmental problems that were relevant to their daily lives and cultural surroundings. During the cultural understanding phase, students discussed the relationship between global warming phenomena, local wisdom, and cultural values. The LKPD, illustrated in Figure 3, guided students in comparing cultural perspectives with scientific explanations. During the collaboration phase, students worked in groups to analyze cases provided in the LKPD, such as environmental changes occurring in their local region. These activities encouraged students to exchange ideas, solve problems collaboratively, and construct scientific understanding through culturally meaningful contexts.

Figure 1. Global warming podcast

Figure 2. E-assessment platform

Figure 3. LKPD model CRTT

The critical reflection phase was conducted by asking students to respond to open-ended questions in the LKPD. Through this activity, students reflected on their understanding of global warming by evaluating both scientific concepts and cultural implications. The e-assessment platform, shown in Figure 2, was used at the end of each session in the form of formative quizzes. This platform was intended to monitor students' learning progress, provide immediate feedback, and support continuous evaluation during the implementation of CRTT-assisted learning.

The control class was taught using the Discovery Learning model combined with lecture-based instruction. The implementation in this class also consisted of six sessions of 90 minutes and covered the same global warming material. Learning activities in the control class included teacher explanation of concepts through lectures, guided discovery using textbook-based problems, completion of standard LKPD containing structured exercises without cultural integration, and teacher-led class discussions to confirm students' conceptual understanding. Assessment in the control class was conducted through conventional written exercises at the end of selected sessions, without the use of a digital assessment platform.

c. Final Stage

The final stage focused on processing, analyzing, and interpreting the data obtained during the research implementation. The pretest and posttest results from both the experimental and control groups were first organized and coded based on the assessed variables, namely students' science literacy and critical thinking skills. The data were then checked to ensure completeness, accuracy, and consistency before being subjected to statistical analysis.

Data analysis was conducted to determine whether the podcast-assisted Culturally Responsive Transformative Teaching (CRTT) model integrated with e-assessment had a significant effect on students' science literacy and critical thinking skills. The analysis included the comparison of pretest and posttest scores within each group, as well as the comparison of learning outcomes between the experimental and control groups. This process was intended to identify the extent to which the treatment

contributed to students' improvement after the learning intervention.

The results of the statistical analysis were then interpreted in relation to the research objectives and hypotheses. The findings were used to evaluate the effectiveness of the integrated instructional package, consisting of the CRTT model, podcast media, culture-based LKPD, and e-assessment. The final interpretation also considered the characteristics of the quasi-experimental design, particularly the fact that the treatment represented a combined learning intervention. Therefore, any observed improvement in students' science literacy and critical thinking skills was interpreted as the effect of the integrated podcast-assisted CRTT model supported by e-assessment, rather than the isolated effect of a single component.

4. Instrument

The instruments used in this study consisted of science literacy and critical thinking tests. The science literacy instrument was developed in the form of 15 essay items based on Shwartz's science literacy framework, covering content, context, higher-order learning skills, and attitude dimensions. The critical thinking instrument consisted of five essay items developed based on Ennis's critical thinking indicators, including providing simple explanations, building basic skills, drawing conclusions, and providing further explanation (Table 2).

Table 2. Indicators of Science Literacy and Critical Thinking Instruments

No.	Instrument	Indicator	Sub-Indicator	Number of Items
1	Science Literacy Test	Content	Explaining the sources of greenhouse gas emissions	7
2	Science Literacy Test	Context	Explaining the impact of global warming on the environment	5
3	Science Literacy Test	Higher-Order Learning Skills	Designing simple solutions based on chemical concepts	1
4	Science Literacy Test	Attitude	Demonstrating environmental awareness	2
5	Critical Thinking Test	Providing simple explanations	Asking and answering questions about an explanation	1
6	Critical Thinking Test	Building basic skills	Observing and considering observation reports	1
7	Critical Thinking Test	Drawing conclusions	Deducing and considering the results of deduction	1
8	Critical Thinking Test	Drawing conclusions	Inducing and considering the results of induction	1
9	Critical Thinking Test	Providing further explanation	Identifying terms and considering definitions	1

The instruments were validated by two expert validators before being used in the research. Content validity was analyzed using the Gregory formula, and the results indicated that the instruments were valid. Reliability testing was also conducted using Cronbach's Alpha. The science literacy instrument obtained a Cronbach's Alpha value of 0.922, indicating very high reliability, while the critical thinking instrument obtained a Cronbach's Alpha value

of 0.80, indicating high reliability. These results show that both instruments were valid and reliable for measuring students' science literacy and critical thinking skills in the context of global warming learning.

5. Data Collection

Data collection in this study was conducted using test and non-test techniques. The non-test technique was carried out through documentation and observation. Documentation was used to collect students' prior chemistry scores from school records. These scores were used to examine the homogeneity of students' initial academic abilities across the available classes before determining the experimental and control groups. Observation sheets were also used to monitor the implementation of learning activities and ensure that the treatment was conducted according to the planned learning procedures.

The test technique was used to collect the main research data. The science literacy and critical thinking tests were administered to both the experimental and control groups as pretests and posttests. The pretest was conducted before the intervention to measure students' initial science literacy and critical thinking skills, while the posttest was conducted after the intervention to examine changes in students' abilities after the learning process.

The experimental group received instruction using the Culturally Responsive Transformative Teaching (CRTT) model assisted by podcast media, culture-based LKPD, and e-assessment. The control group received instruction through the Discovery Learning model supported by conventional learning media. Both groups studied the same global warming topic, were taught by the same teacher, and received comparable learning objectives, content coverage, and time allocation.

6. Data Analysis

Data analysis was conducted quantitatively to determine the effect of the podcast-assisted CRTT model integrated with e-assessment on students' science literacy and critical thinking skills. The analysis began with descriptive statistics, including mean, standard deviation, minimum score, maximum score, and percentage improvement. This analysis was used to describe students' pretest and posttest performance in both the experimental and control groups. Learning improvement was further analyzed using the normalized gain score, or N-gain. The N-gain score was used to determine the level of improvement in students' learning outcomes by comparing pretest and posttest scores. The formula used was as follows:

$$N\ Gain\ = \frac{SPost - Spre}{Smax - Spre} \ldots\ldots\ldots (3)$$

The obtained N-gain scores were then interpreted using three categories: high if $g > 0.70$, medium if $0.30 \leq g \leq 0.70$, and low if $g < 0.30$. A high N-gain score indicates that the learning process was highly effective in improving students' science literacy and critical thinking skills, while medium and low N-gain scores indicate moderate and limited improvement, respectively.

Prerequisite tests were then conducted before inferential analysis. The normality test was used to determine whether the data were normally distributed, while the homogeneity test

was used to examine whether the variances between groups were equal. The results of these prerequisite tests determined the appropriate statistical test for each dependent variable.

Inferential analysis was conducted separately for science literacy and critical thinking skills. For science literacy, the normality test showed that one group did not meet the assumption of normal distribution; therefore, the Mann–Whitney U test was used to examine differences between the experimental and control groups. For critical thinking skills, the data met the assumptions of normality and homogeneity; therefore, an independent-samples t-test was used. The Kruskal–Wallis test was not used because this study involved only two groups, making the Mann–Whitney U test more appropriate for non-parametric comparison.

Effect size analysis was also conducted to strengthen the interpretation of the statistical results. Cohen's d was used for the independent-samples t-test, while the effect size r was used for the Mann–Whitney U test. This analysis provided information not only about the statistical significance of the treatment effect but also about the magnitude of the effect of the podcast-assisted CRTT model integrated with e-assessment on students' science literacy and critical thinking skills.

RESULT AND DISCUSSION

1. Implementation of the Culturally Responsive Transformative Teaching (CRTT) Learning Model

The implementation of the CRTT model in this study is not only reflected in procedural stages but also in observable student learning behaviors and cognitive engagement patterns. Classroom observations indicate that student participation increased progressively across stages, with the most significant engagement occurring during collaboration and critical reflection.

Figure 4. Stages in learning on the CRTT model

Learning implementation in this study is first described to provide empirical context before interpreting the results. The focus is not on re-explaining theory, but on how the learning model was applied in the classroom. Learning model *Culturally Responsive Transformative Teaching* (CRTT) is a student- centered learning approach that integrates local cultural values with the principles of *Transformative Learning* to improve science literacy and critical thinking skills [5]. In this study, the implementation of CRTT was observed through five stages, namely self-identification, cultural understanding, collaboration, critical reflection, and transformative construction. During implementation, students actively engaged in identifying cultural experiences related to global warming, discussing

socioscientific issues, and presenting problem-solving ideas.

Classroom observations did not only show general engagement, but revealed specific behavioral patterns across stages. In the self-identification stage, most students were able to relate global warming issues to daily practices such as waste burning and energy use, indicating activation of prior knowledge as a cognitive entry point for literacy development. During the cultural understanding and collaboration stages, students demonstrated increased use of scientific vocabulary and argumentation when discussing the causes and impacts of global warming, suggesting that these stages contributed directly to the development of science literacy, particularly in explaining phenomena and interpreting data [8].

Furthermore, the critical reflection stage appeared to play a dominant role in enhancing critical thinking skills. Students were observed questioning the validity of information presented in the podcast and comparing it with their own experiences, indicating engagement in higher-order thinking processes such as evaluation and reasoning.

This suggests that CRTT does not only promote participation, but also facilitates cognitive restructuring, where students reasses their initial assumptions using scientific evidence. Previous studies by Rahmawati have shown that these stages allow students to explore their cultural identities, collaborate in reflective discussions, as well as build a transformative understanding of science concepts through cultural engagement [14]. The transformative construction stage further strengthened both outcomes, as students synthesized discussion results into solution-oriented presentations. This stage likely contributed to both science literacy (through application of concepts) and critical thinking (through decision-making and justification). Thus, each CRTT stage contributed differently: early stages supported conceptual understanding, while later stages strengthened evaluation and application skills, explaining the higher posttest and N-gain results in the experimental group [15].

Stages Cultural Understanding and Collaboration Encourage students to analyze the relationship between cultural practices, human activities, and chemical concepts, as well as discuss the problem of global warming in groups. This process trains scientific communication, cooperation, and problem- solving skills, thereby supporting the development of students' science literacy and critical thinking [5]. Next, at the stage Critical Reflection, students are directed to conduct critical reflection through analytical questions given by teachers, so that students are able to evaluate scientific information and make decisions based on relevant evidence [6].

The final stage, namely transformative construction, focused on presenting the results of the discussion and problem-solving solutions, which were assessed using E-Assessment objectively. Overall, the implementation of the CRTT model was supported by podcast media and E-Assessment able to create active, contextual, and meaningful learning and support the

improvement of science literacy and students' critical thinking skills [5].

2. Implementation of Media Podcast and E-Assessment

Podcast media is used as a means of presenting initial material and strengthening concepts in CRTT learning. Unlike conventional teacher explanations, the podcast provided a narrative and contextual representation of global warming issues, which appeared to increase students' emotional and cognitive engagement at the beginning of learning. Students were observed to pay more attention and respond more actively to discussion prompts after listening to the podcast, indicating that the media functioned as an effective trigger for situational interest and contextual understanding. This is in line with the findings of Adha, (2022) who stated that podcasts are suitable for use as media. Thus, the use of podcasts in learning supports active and contextual learning [16]. Through podcasts, the phenomenon of global warming is presented narratively and contextually, which helps students understand chemical concepts in a more meaningful way [17].

The role of the podcast was particularly evident in the self-identification and cultural understanding stages, where students were able to connect scientific concepts with real-life experiences more easily compared to traditional instruction. This suggests that the podcast did not merely deliver information, but functioned as a cognitive scaffold that supported contextualization of abstract chemical concepts. More importantly, E-assessment did not only function as a scoring tool, but as a formative feedback mechanism. Immediate feedback enabled students to identify misconceptions and revise their understanding during the learning process, particularly after the critical reflection stage. This iterative feedback process likely contributed to the higher improvement (N-gain) observed in the experimental group [18]. E- assessment was primarily used for formative evaluation, allowing students to receive immediate feedback and reflect on their understanding during the learning process [19]. Podcast media integration and E- Assessment in the CRTT model as a whole supports the creation of learning that is active, adaptive, and relevant to the characteristics of 21st century learning [11].

The integration of digital learning media such as podcasts and e-assessments in the CRTT model as a whole supports the creation of Learning that is active, adaptive and relevant to the characteristics of 21st century learning. The use of digital media and technology has been shown to increase student engagement, creativity, and critical thinking skills that are essential components of 21st century learning in the context of primary education [20]. In addition, the application of Technology in Formative Assessment Such digital tools show significant contributions to active student engagement and adaptive learning that is responsive to the individual learning needs of students in the digital age [21].

The integration of podcast and E-assessment within the CRTT framework created a complementary mechanism: the podcast stimulated contextual understanding at the beginning, while E-assessment

reinforced reflection and conceptual correction at later stages. This interaction between media and pedagogy explains why the intervention was more effective than conventional learning, rather than the effect of each component in isolation [22].

3. The Influence of the CRTT Learning Model Assisted by Podcasts and e-Assessments on Science Literacy

a. Pretest and posttest data results

Table 3 shows the science literacy pretest and posttest scores in the control and experimental classes. The pretest mean score of the control class was 54.36, while the experimental class obtained 58.80, with a mean difference of 4.44. This relatively small difference indicates that both groups had comparable initial science literacy, although the experimental class showed slightly higher prior knowledge. The posttest results show a clearer difference, with the control class obtaining a mean score of 78.85 and the experimental class achieving 90.92, resulting in a mean difference of 12.07. This finding indicates that students taught using the CRTT model assisted by podcast media, LKPD, and e-assessment demonstrated stronger science literacy than those taught using the Discovery Learning model. The improvement in the experimental class suggests that CRTT-based learning strengthened students' ability to interpret scientific phenomena and connect global warming concepts with real-life and socio-cultural contexts.

Table 3. Description of Science Literacy Pretest and Posttest Scores

Class	Pretest Lowest Score	Pretest Highest Score	Pretest Mean	Posttest Lowest Score	Posttest Highest Score	Posttest Mean
Control	27	93	54.36	73	93	78.85
Experimental	20	86	58.80	87	100	90.92

Table 4. Comparison of Science Literacy N-Gain Scores

Class	Average N-Gain	Category
Experimental	0.752	High
Control	0.397	Medium

The higher posttest achievement in the experimental class also reflects the cognitive benefits of aligning scientific instruction with students' socio-cultural experiences. When learning is situated within familiar cultural contexts, the cognitive load required to process abstract scientific concepts can be reduced, allowing students to allocate more mental resources to higher-order tasks such as scientific reasoning, interpretation, and evaluation [30]. This alignment may also foster a stronger sense of ownership in the learning process because students perceive global warming not merely as an isolated classroom topic, but as an environmental issue directly connected to their own communities.

Table 4 shows that the experimental class obtained an average N-Gain score of 0.752, categorized as high, while the control class obtained 0.397, categorized as medium. These results indicate that the

improvement in science literacy was greater in the experimental class. This improvement was likely driven by the combination of contextual learning through cultural integration, collaborative discussion, reflective evaluation, podcast-based contextual stimulation, and e-assessment. In contrast, the moderate N-Gain in the control class suggests that conventional learning may support knowledge acquisition but is less effective in promoting deeper conceptual understanding and application.

The integration of digital tools alongside the CRTT model also played an important role in maintaining student engagement and providing immediate reinforcement of concepts. Previous research indicates that the combination of student-centered pedagogical models with digital assessment platforms can enhance the retention of complex scientific data [21]. In this study, the use of e-assessment likely acted as a bridge by providing real-time feedback that helped students refine their scientific interpretations and correct misconceptions immediately, ultimately contributing to the superior posttest performance observed in the experimental class.

b. Statistical Analysis

Table 5 shows the results of the science literacy normality test in experimental and control classes. Based on this data, the experimental class had a significance value of 0.149, while the control group had a significance value of 0.000. Therefore, it can be concluded that science literacy skills in the experiment class are normally distributed while the control class is not normally distributed.

Table 5. A test of science literacy

Classes	Sig.	Conclusion
Experiments	0,149	Data Normal
Controls	0,000	Abnormal Data

Table 6. Test of the homogeneity of science literacy

Classes	Sig.	Conclusion
Experiments Controls	0,521	Homogeneous Data

Table 6 shows the results of the science literacy homogeneity test in the experimental and control classes. Based on this data, the homogeneity test obtained a significance value of 0.521 with a sig value of >0.05. Therefore, it can be concluded that the data on science literacy ability in the experimental and control classes are homogeneous. A non-parametric statistical test, namely the Mann-Whitney test, is used.

Table 7 shows that the results of the science literacy hypothesis test use Mann-Whitney. The results of the experiment class and control class tests had a significance value of 0.001, which had a sig value of < 0.05. Therefore, there is a significant difference between the experimental class and the control class. The hypothesis test uses the Mann- Whitney test because the data obtained is abnormal. Since the Mann-Whitney test evaluates the differences in ranks rather than means, the result indicates a consistent shift in the distribution of science literacy scores across the entire experimental group, rather than just an improvement among top-performing students. This

suggests that the instructional intervention was robust enough to overcome the non-normal distribution of initial student abilities, effectively elevating the baseline of scientific literacy for a diverse range of learners [32].

Table 7. Science literacy hypothesis test

Classes	Sig.	Conclusion
Experiments Controls	0,001	There are differences

4. The Influence of the CRTT Learning Model with the Help of Podcasts and e-Assessments on Critical Thinking Skills

a. Pretest and Posttest data Result

Table 8 presents the critical thinking scores of the control and experimental classes in the pretest and posttest. The pretest mean score of the control class was 53.75, while the experimental class obtained 53.10, with a very small mean difference of 0.65. This result indicates that both groups had relatively equivalent initial critical thinking abilities before the intervention.

Posttest results in Table 8 show a clearer difference between the two groups. The control class obtained a mean score of 74.31, while the experimental class achieved 86.53, with a mean difference of 12.22. This finding suggests that students taught using the CRTT model assisted by podcast media, LKPD, and e-assessment demonstrated stronger critical thinking skills than those taught using the Discovery Learning model. The higher posttest score in the experimental class indicates that CRTT-based learning supported higher-order thinking processes, particularly analysis, evaluation, reasoning, and evidence-based argument construction.

Table 8. Description of Critical Thinking Pretest and Posttest Scores

Class	Pretest Lowest Score	Pretest Highest Score	Pretest Mean	Posttest Lowest Score	Posttest Highest Score	Posttest Mean
Control	38	80	53.75	65	95	74.31
Experimental	40	80	53.10	80	95	86.53

Table 9 shows that the experimental class obtained an average N-Gain score of 0.71, categorized as high, while the control class obtained 0.43, categorized as medium. These results indicate that the improvement in critical thinking skills was greater in the experimental class. This improvement was likely supported by structured reflection activities, collaborative problem-solving, and culturally contextual learning embedded in the CRTT model.

The substantial improvement in the experimental class highlights the effectiveness of CRTT in fostering metacognitive awareness and deeper reasoning. Through the critical reflection and transformative construction stages, students were encouraged to move beyond passive reception of information and engage in active inquiry by examining their assumptions, evaluating scientific evidence, and constructing arguments. This reflective process is essential for developing the ability to analyze complex socioscientific issues such as global warming because students must

synthesize diverse perspectives into coherent and evidence-based reasoning [33].

Table 9. Comparison of Critical Thinking N-Gain Scores

Class	Average N-Gain	Category
Experimental	0.71	High
Control	0.43	Medium

b. Statistical Analysis

Table 10. Test of the normality of critical thinking skills

Classes	Sig.	Conclusion
Experiments	0,194	Data Normal
Controls	0,103	Data Normal

Table 10 shows the results of the normality test of critical thinking skills in the experimental and control classes. Based on this data, the experimental class had a significance of 0.194 and a Sig value of >0.05, while the control group had a value of 0.103 and a Sig. value of >0.05. Therefore, it can be concluded that the CRTT model has a strong effect on improving critical thinking skills. Importantly, this effect can be interpreted as the result of repeated engagement in reflective and evaluative tasks, rather than passive content reception.

Table 11. Homogeneity test of critical thinking ability

Classes	Sig.	Conclusion
Experiments Controls	0,987	Homogeneous Data

Table 11 shows the results of the homogeneity test of critical thinking skills in the experimental and control classes. Based on this data, the homogeneity test of the experimental and control classes obtained a significance value of 0.987 with a Sig.> value of 0.05. Therefore, the data on the critical thinking ability of the experimental and control classes are homogeneous. Therefore, further tests are needed using parametric statistical tests, namely independent sample t-tests.

Table 12. Critical thinking skills hypothesis test

Classes	Sig.	Conclusion
Experiments Controls	0,000	There are differences

Table 12 shows the result of the independent-samples t-test for critical thinking skills. The significance value was 0.000, or $p < 0.05$, indicating a significant difference between the experimental and control classes. This finding shows that the podcast-assisted CRTT learning model integrated with e-assessment had a significant effect on students' critical thinking skills. The significant improvement in the experimental class can be associated with the learning activities embedded in the CRTT model, particularly reflective discussion, collaborative problem-solving, and evidence-based evaluation. These activities encouraged students to analyze information, examine assumptions, and construct arguments related to global warming issues. Therefore, the use of the podcast-assisted CRTT model supported by e-assessment did not only improve students' content understanding, but also strengthened their ability to think critically through repeated engagement in reflective and evaluative tasks.

c. Hypothesis Testing

Table 13. Simultaneous hypothesis test results

Aspect	Sig. Value	Conclusion
The influence of the podcast-assisted CRTT learning model integrated with e-assessment on students' science literacy and critical thinking skills	0.000	H_0 rejected

Based on Table 13, results of the analysis in the table, a significance value of 0.000 was obtained with a Sig. Value of < 0.05, so that the null hypothesis (H_0) was rejected. The significant result (Sig. = 0.000) indicates that the CRTT model supported by podcasts and E-assessment has a combined effect on both science literacy and critical thinking skills. This suggests that these two competencies are not developed independently, but are interconnected through learning processes that involve contextual understanding, reflection, and problem-solving.

Hypothesis testing using the Kruskal–Wallis test also showed a significance value of 0.000, which further corroborated the H_0 rejection. The use of the Kruskal–Wallis test further confirms that the intervention effect is consistent across different aspects of learning outcomes. This reinforces the argument that the effectiveness of CRTT lies in its integrateddesign where cultural relevance, collaborative learning, and reflective evaluation work synergistically to enhance multiple cognitive domains [31].

The Kruskal–Wallis analysis used to examine the influence of different learning approaches on student learning outcomes reflects methodological precision in evaluating the influence of an educational intervention. The results of this study confirm the importance of the role of learning strategies, teacher beliefs, and pedagogical attitudes in shaping students' learning experiences, which ultimately have an impact on improving learning achievement more broadly, the implications of this research contribute to the development of teacher education programs that are oriented towards the readiness of prospective educators in implementing innovative learning practices in the field of science education [8].

Overall, the findings highlight that the improvement in learning outcomes is not merely due to increased activity, but due to the quality of cognitive engagement facilitated by the CRTT stages and supported by digital media. This provides empirical support for constructivist and transformative learning theories, which emphasize the importance of meaningful, contextual, and reflective learning experiences in developing higher-order thinking skills [8]. The utilization of the Kruskal–Wallis test to analyze the impact of different instructional approaches underscores the necessity of employing non-parametric methods when assessing complex educational interventions where data may not meet the assumptions of normality. This methodological choice ensures that the observed improvements in critical thinking and science literacy are statistically sound and representative of a

genuine shift in student performance across the experimental group. Furthermore, the effectiveness of the CRTT stages suggests that when technology is integrated not just as a tool, but as a scaffold for cognitive engagement, it significantly amplifies the transformative potential of the curriculum, allowing students to internalize scientific concepts through a lens of cultural and social relevance [34]. Integration of technology in formative assessment (formative assessment) can improve innovation in social studies learning in the 21st century, so that the evaluation process becomes more effective, interactive, and supports students' skill [23][35].

CONCLUSION

Based on the results of this study, the findings suggest the potential effectiveness of the Culturally Responsive Transformative Teaching (CRTT) learning model assisted by podcast media and e-assessment in improving students' science literacy and critical thinking skills on global warming materials. The results of the Kruskal–Wallis test, which indicate a significance value of < 0.05, show that there are statistically significant differences in students' abilities before and after the implementation of the instructional approach. However, these findings should be interpreted with caution. The intervention in this study involved multiple components simultaneously, including CRTT-based instruction, podcast media, and e-assessment tools, making it difficult to isolate the individual contribution of each element. In addition, limitations related to the completeness of instrument documentation and the consistency of inferential reporting should be acknowledged. Therefore, the results do not establish a definitive causal effect, but rather indicate a promising direction for instructional innovation in this context.

The integration of local culture through the CRTT framework, combined with contextual learning via podcast media and the use of e-assessment for timely feedback, appears to support more active, meaningful, and relevant learning experiences aligned with students' characteristics. Future research is recommended to employ more controlled experimental designs, improve instrument transparency, and ensure rigorous analytical consistency to validate and extend these findings. The study concludes that the integration of Culturally Responsive Transformative Teaching (CRTT), podcast-based learning, and digital e-assessment offers a powerful synergy for modern chemistry education. By grounding abstract scientific concepts like global warming in the students' own cultural narratives and leveraging accessible digital tools, the intervention successfully bridges the gap between theoretical knowledge and real-world application. While the individual impact of each component requires further isolation, the collective success of this model suggests that a holistic approach—addressing cognitive, technological, and socio-cultural dimensions is essential for fostering the 21st-century competencies required in an increasingly complex and interconnected world.

ACKNOWLEDGEMENT

The authors would like to acknowledge the funding support provided by Universitas Sebelas Maret through the Indonesian Collaborative Research Scheme (Riset Kolaborasi Indonesia/RKI) Scheme C (Collaboration among 24 PTNBH with Foreign Research Institutions or Foreign Higher Education Institutions) under contract number 431/UN27.22/PT.01.04/2025.

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