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Yuli Rahmawati

Alin Mardiah

Elisabeth Taylor
Edith Cowan University

Peter Charles Taylor

Achmad Ridwan

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Chemistry Learning through Culturally Responsive Transformative Teaching (CRTT): Educating Indonesian High School Students for Cultural Sustainability

Yuli Rahmawati [1,*], Alin Mardiah [1], Elisabeth Taylor [2], Peter Charles Taylor [3] and Achmad Ridwan [1]

[1] Department of Chemistry Education, Universitas Negeri Jakarta, Jakarta 13220, Indonesia; alinmardiah_1311820004@mhs.unj.ac.id (A.M.); achmadridwan@unj.ac.id (A.R.)
[2] School of Education, Edith Cowan University, Mount Lawley, WA 6050, Australia; e.taylor@ecu.edu.au
[3] School of Education, Murdoch University, Murdoch, WA 6150, Australia; p.taylor@murdoch.edu.au
* Correspondence: yrahmawati@unj.ac.id

Abstract: According to the United Nations Educational, Scientific, and Cultural Organization (UNESCO), culture provides the transformative dimension for ensuring the development process of the United Nations' 2030 Agenda for Sustainable Development. As one of the key drivers in the implementation of the United Nations' Sustainable Development Goals, culture ensures a people-centered and context-relevant approach that cuts across a range of policy areas and, thus, in the context of quality education promotes the development of human resources for cultural and environmental sustainability. It is in this context that we report on a study aimed at developing students' cultural identity and supporting the younger generation in preserving their cultural heritage, whilst learning chemistry concepts at the same time. The culturally responsive transformative teaching (CRTT) model served as a theoretical framework for the research to engage students in culture-based, high school chemistry learning by utilizing specially designed ethnochemistry texts that highlighted the relationship between cultural values and chemistry concepts. Case studies were conducted within the interpretive research paradigm and involved 149 students from four high schools in four Indonesian provinces, namely Banten, west Java, Bangka Belitung, and south Sumatra. In particular, we were interested in understanding how well students engage in this innovative transformative learning model, designed to educate them about cultural sustainability. We generated data by means of students' reflective journals, semi-structured interviews with students, and classroom observations. In general, the results from the research strongly suggest that students involved in cultural identity reflection, engaged in cultural-based chemistry learning, explored cultural heritage through a chemistry lens, applied social etiquette and ethics, and developed cultural heritage preservation awareness. These are important aspects of cultural sustainability. The results imply that culturally responsive chemistry education has great potential for educating students and empowering them as conservationists of Indonesian culture. Further research on empowering students on cultural sustainability with other ethnochemistry topics within Indonesian cultural contexts is needed to further investigate the CRTT model's broader efficacy.

Keywords: CRTT model; chemistry learning; Indonesian culture; cultural sustainability

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1. Introduction

As the home of 1340 ethnic groups, 2500 languages, and a rich cultural heritage, Indonesia is known as a superpower in terms of culture [1]. Globalization, which has a tendency to erode indigenous cultural values, has become a major challenge for Indonesia in trying to preserve its rich cultural heritage. Cultural imperialism often comes with the development of individualism in society [2], running counter to traditional local cultures. Education must play a strategic role in anticipating and counteracting the ongoing loss of national culture and traditions through globalization. By bringing cultural values into the curriculum, teachers can create a learning environment that supports students by enabling them to have a direct learning experience on their cultural identities [3].

The implementation of culture-based learning is important for providing space for the formation of students' socio-emotional well-being in the form of cultural identity, self-efficacy, and social relationships, which in turn positively impact students' skills and cultural awareness, literacy, and learning outcomes [4–6]. An established strategy for integrating culture into the classroom is through the culturally responsive teaching (CRT) model, which uses students' cultural backgrounds, perspectives, and experiences as an effective teaching channel [7–9]. A more recent development is the culturally responsive transformative teaching (CRTT) model. This approach was developed by marrying the principles of CRT with transformative learning [10]. Transformative learning activities involve students by reflecting critically on their implicit assumptions and values, negotiating and validating their cultural beliefs and values through mutually respectful discourse, collaborating to design social action based on the principles of cultural sustainability, and evaluating the impact of these actions [11,12]. For this study, a CRTT model was designed to: (1) develop students' academic chemistry knowledge and its relationship with their local culture, (2) enable students to learn how to respect and empathize with cultural diversity, and (3) empower students as communicative agents for cultural sustainability [13].

Chemistry is one of the science disciplines that is often misunderstood in the public eye. Chemistry tends to be viewed as an abstract science, since it uses three levels of representation: macroscopic, submicroscopic, and symbolic [14]. However, it is less well known that it is closely linked to everyday life and 'green' chemistry, in particular, plays an essential role in tackling today's global challenges by ensuring future environmental sustainability [15]. It is true that chemistry concepts can be experienced as unduly abstract when students see chemistry as separate from their daily lives. Students often experience difficulties with how chemistry concepts are traditionally taught, particularly when their learning is based primarily on methods such as memorizing complex chemistry concepts [12,14,15]. For example, when teaching the concept of chemical reactions, teachers usually start the lesson with a definition of the concept, followed by examples using symbols and formulas for chemical reactions, but without providing experimental experience. This can leave students with the impression that chemistry is unduly abstract due to a lack of connection with their daily lives, a view that is compounded by the use of unfamiliar scientific language [16,17]. This perspective is supported by Childs et al., who highlighted that many students find chemistry a boring subject and cannot apply their chemical understanding in real-life contexts [18]. Thus, if chemistry learning is to successfully engage students it must be supported by activities that integrate chemical phenomena with everyday life, so that students can improve their understanding of concepts and achieve the expected levels of competency [19,20]. Formal chemistry education, through which students learn scientific concepts and language, plays an important role in protecting and transmitting cultural heritage from one generation to another. Through chemical understanding, students may gain a deep apprehension of the composition and structure of inherited materials and the reactions that occur to obtain information related to the source, purpose and period of creation, manufacturing technology, and others, to be able to protect and preserve their cultural heritage [21]. However, establishing connections between scientific concepts, processes, and contexts with the cultural aspects of students' daily lives is often hampered due to teachers' limited abilities in this area, as chemistry education rarely considers local culture [22], which is the problem this research aimed to address.

The CRTT learning model, which served as the theoretical framework underpinning this study, was designed to enable students to explore various cultures across Indonesia, a multicultural country with greatly diverse ethnic and cultural characteristics [23], through five stages of learning: self-identification, cultural understanding, collaboration, critical reflective thinking, and transformative construction [24]. These five stages were intended to provide students with opportunities to develop self-understanding in relation to their character and cultural identities. Local traditions, such as typical foods, visual art, and social and ritualistic practices, known to students from their home life, impact strongly on the cultural identities associated with students' daily lives. Learning chemistry by connecting local culture, science, traditional practices, and scientific knowledge has been developed in a range of countries, including Brazil, Canada and Tanzania, and has been shown to have a positive impact on students' learning experiences [25–27]. Therefore, this study was designed to build students' awareness of cultural identity by integrating local cultures with chemistry learning, with the aim of developing students as agents of cultural sustainability.

2. Transformative Learning for Cultural Sustainability

2.1. Cultural Sustainability

Culture is central to sustainability awareness in indigenous communities, as it constitutes and permeates all aspects of life [28]. However, culture is often reduced to a unified or essentialized abstraction that seeks to explain the concept through a finite approach that yields a less diverse and complex conception of culture [29]. On the other hand, UNESCO defines culture as not limited to arts and literature, but as comprising a way of life, fundamental human rights, value systems, traditions and beliefs [30]. Principles of sustainability are central to the world's indigenous cultures and should not be ignored when considering the fascinating trajectory that indigenous peoples have followed over the centuries [28,31].

The links between sustainability and culture have been widely discussed in the last decade. The goals for sustainable development have been well-defined by the United Nations and culture has become a focus of debate that has received special attention as a core aspect of sustainability [32,33]. Soini and Birkeland have defined cultural sustainability as a broad understanding that places culture as a condition and premise for actualization in action, meaning and communication [34]. Culture in this context refers to the nature of human social groups, symbolic patterns, norms and customs, as well as rules that specifically apply to human communities [35]. Culture is a distinguishing characteristic of one group of humans from other groups [36]. For UNESCO, culture is one of four core dimensions of sustainability: ecological, economic, social, and cultural.

Cultural sustainability refers to the ability to maintain cultural identity and enable change in harmony with cultural values [37]. It emphasizes a sense of progressive understanding of culture and recognizing the needs of a society. Acton et al. describe cultural sustainability as enabling access to cultural resources between and within generations [29]. The theoretical background to cultural sustainability begins with close parallels between natural and cultural capital. Natural capital includes natural resources, ecosystems, and biodiversity, whereas cultural capital includes cultural property (tangible and intangible), cultural networks and support systems, and cultural diversity [28]. The tangible part includes architecture, sculpture, painting, archaeology, and man-made landscape monuments, while the intangible part includes practices, designs, illustrations, attitudes, knowledge, and skills [30,32]. Cultural sustainability corresponds to a comprehensive definition of sustainable development that meets immediate needs without compromising those of future generations, including promoting engagement and the preservation of cultural heritage [38].

According to Soini and Birkeland, there are three essential roles culture plays within sustainable development, known as representations: culture in sustainability, culture for sustainability, and culture as sustainability [34]. The first representation, culture in sustainability, aims to place culture as an equal condition with other pillars of research and policies related to sustainability. Culture in sustainability emphasizes that the independent role of culture can be interpreted as a necessary means for the transformation of society. With a view to development, culture in sustainability mandates maintaining and preserving culture as capital in its various forms, including art and knowledge, which are important to be passed on to the next generations. The second representation, culture for sustainability, interprets culture as a mediator to achieve economic, social, and ecological sustainability.

Culture for sustainability aims to deepen the understanding of nature as a form of human capital towards cultural constituents that lead the transformation of society to more sustainable conditions. This elaboration reflects that the first and second representations focus on culture as a result, or part of, a sustainable development process with a specific purpose. Furthermore, the third representation, cultural as sustainability, places more emphasis on the processes that are continuously evolving with the goal of transformation [39].

2.2. Chemistry Education and Its Role in Cultural Sustainability

Education is a strategic sector for promoting sustainability, including cultural sustainability. Thus, for a curriculum to accommodate cultural sustainability, the learning process needs to consider various aspects, such as community diversification and cultural identity [40]. Chemistry, as a discipline rooted in science, has broad applications and cultural implications. Everyone can find chemistry in everyday life, especially in the food we consume, the air we breathe, the emotions we feel, etc. From this perspective, the human body is a giant collection of chemical compounds that bind together [41]. It stands to reason, therefore, that the teaching of chemistry must be linked to everyday experiences. Adopting a constructivist perspective, this can be conducted by tapping into students' prior knowledge [42,43]. According to Dalgety et al., chemistry is not just a collection of knowledge but also a type of culture, with its own patterns of learning on thinking and acting that are transmitted through theory, skills, and values [44]. Treagust et al. suggested that chemistry learning be adapted to students' characteristics and that learning methods enable students to master chemistry concepts thoroughly, not only by memorization but also through analyzing and linking concepts [45]. Therefore, chemistry learning should consider various student characteristics, such as achievement levels, gender, and students' sociocultural backgrounds [24,46]. This requires teachers to understand students' cultural backgrounds in order to be able to involve them in learning experiences that can form students' appreciation of their cultures [13,47].

2.3. Culturally Responsive Teaching (CRT) Model

CRT is a learning approach that engages students' cultural needs and experiences, especially when there are diverse cultures and ethnicities in the same classroom [10,48]. The concept stems from the need for students to receive specially designed materials that enrich their learning in order to prepare them as functional participants in a diverse society [49]. Student participation in social life, be it in the classroom or outside the classroom, must be built on a foundation of meaningful and positive relationships between the two contexts [50]. Gay asserts that CRT is a very different pedagogical paradigm with five key principles: (1) recognizing the existence of cultural heritage from various ethnic groups, both as something that can influence student attitudes, approaches to learning, and content to be taught according to the formal curriculum; (2) building meaningful relationships between the experiences students encounter at home and academic teaching at school; (3) using a range of learning strategies that are connected to a variety of ethnic and cultural diversity; (4) teaching students to know and love their cultural heritage and respect the culture of others; and (5) combining multicultural information, resources, and skills routinely taught in schools [49].

According to Hernandez et al., the CRT pedagogical model has five primary foci: (1) content integration, that is, merging scientific chemical content with content drawn from many cultures, thereby fostering positive teacher–student relationships and maintaining high expectations for all students; (2) facilitating knowledge construction, which refers to the teacher's ability to construct what students know to help them learn and think critically, independently, and openly in understanding the information obtained; (3) prejudice reduction, which refers to the teacher's ability to use a contextual approach to build a positive environment and a safe classroom regardless of students' race or ethnicity, social class, and language; (4) social justice, which relates to the teacher's willingness to act by encouraging students to ask questions and dare to show their cultural background; and (5) academic development, which refers to the teacher's ability to create opportunities in the classroom that assist all students in achieving academic success and to use teaching strategies that encompass students' diverse cultural backgrounds and learning styles [9] pp. 809–810.

In addition to addressing diversity in the curriculum, culturally responsive learning is important for promoting solidarity as part of increasing students' social competence [51]. Placing students in cultural diversity-based cooperative learning encourages the creation of an inclusive social–emotional climate. It helps them hone their ability to express opinions [52] and facilitates social interaction [53] through the exchange of cultural information, respecting diversity, and constructing shared thinking for creative problem solving [54]. Previous studies on the CRT model in chemistry learning have empowered students to learn chemistry [19]. CRT involves students learning chemistry, developing their cultural identity, and various skills, including working together, responsibility, curiosity, social awareness, creativity, empathetic communication, and self-confidence, categorized into collaboration skills, students' engagement, social and cultural awareness, and higher order thinking skills.

2.4. Culturally Responsive Transformative Teaching (CRTT) Model

In this study, the principles of transformative learning and CRT were combined to design a culturally responsive transformative teaching (CRTT) model [10]. Transformative learning capabilities enable students to more fully participate in democratic processes, as creative and communicative actors [11]. Transformative learning aims not only to develop students' critical reflection skills, from a cognitive, emotional, and spiritual perspective, but also aims to connect them to the social and environmental frameworks in which students shape themselves as human beings [55,56]. Fundamentally, transformative learning involves students by: (1) making visible and reflecting critically on their implicit cultural beliefs and values, (2) validating their cultural beliefs and values in mutually respectful discourse with fellow students, and (3) collaborating to design social action based on principles of social justice, especially principles of cultural sustainability [12].

The CRTT model in this study consisted of five phases: self-identification, cultural understanding, collaboration, critical reflection, and transformative construction [13]. This model aimed to engage students in exploring their cultural identities through critical self-reflection and constructing their chemistry knowledge by interacting with specially designed learning materials in the form of ethnochemistry texts associated with students' cultural backgrounds, daily lives, and the curricula. After reflecting on their cultural identities and connecting their chemistry learning with cultural knowledge, the students engaged in active discussions within groups to enhance their collaboration and communication skills. Next, students engaged in debate to explore differing perspectives and reflect on their values and understanding via critical reflective thinking.

These CRTT learning activities were designed to enable students to transform their values and understanding by reflecting on the key question, "*How have your values and perspectives changed as a result of your learning experience?*" This question relates to five types of engagement in transformative learning [57]: cultural-self knowing (self-realisation), relational knowing (open to difference), critical knowing (sociopolitical awareness), visionary and ethical knowing (over the horizon thinking), and knowing in action (making a difference). By developing these transformative capabilities, students will better understand themselves and develop an enhanced cultural awareness of respect for the culturally different other. A recent closely related study by Rahmawati et al. reported that this CRTT model successfully empowered students' cultural identities and fostered their awareness of cultural diversity [13].

3. Methodology

3.1. Research Design

This study aimed to answer the research question: what is the potential for implementing the culturally responsive transformative teaching (CRTT) model to engage secondary school students in Indonesia in both chemical understanding and student culture to support their role in preserving local cultures? To achieve this goal, the researchers designed a mini-ethnographic inquiry focusing on four case study schools [58] and employing a range of data generation strategies, including reflective journals, semi-structured interviews, and classroom observations. These methods were employed within a constructivist epistemology, enabling researchers to analyze social phenomena in the field to gain insight into participants' life experiences [11,59]. This report presents the results of a sample of exemplary students, whose successful engagement illustrates the potential of this approach to achieve its goals. In line with the nature of interpretive case study research, which aims to study in-depth phenomena in specific contexts, this study did not aim for generalizability.

The study was conducted over 6–8 meetings in four high schools in the four provinces of Banten, west Java, Bangka Belitung, and south Sumatra. A total of 149 eleventh and twelfth grade students were involved in this study. The selection of these two levels was based on: (1) an initial study on concepts in the chemistry curriculum that could be integrated with Indonesian culture, and (2) students' existing understanding of chemistry concepts from previous learning. For ethical reasons all school and student names in this paper are pseudonyms. In detail, the students engaged in this study consisted of 35 grade 11 students at Cinnamon High School (CHS), 42 grade 12 students at Cardamon Secondary School (CSS), 36 grade 11 students at Peppercorn Independent School (PIS), and 36 grade 11 students at Mace Private School (MPS). Consent to participate was obtained from the students who were voluntarily involved in data generation and analysis. The research was conducted in three stages, the preliminary stage, the implementation stage, and the final stage, as shown in Figure 1.

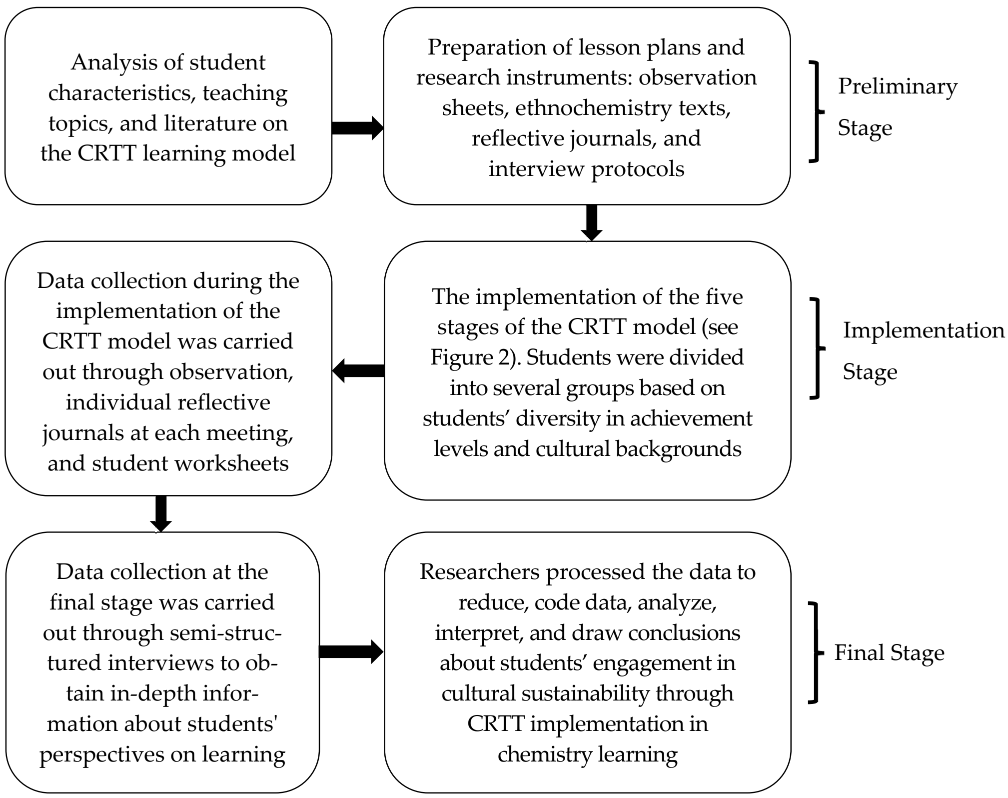

Figure 1. Research flow and data generation.

Four chemistry topics were chosen according to the students' year level and the applicable chemistry curriculum: CHS (colloids), CSS (organic compounds and derivatives), PIS (acids and bases), and MPS (electrolyte and non-electrolyte solutions). The implementation of the CRTT model consisted of five stages [9]: self-identification, cultural understanding, collaboration, critical reflective thinking, and transformative construction, as shown in Figure 2. The model was adapted to focus on chemistry education.

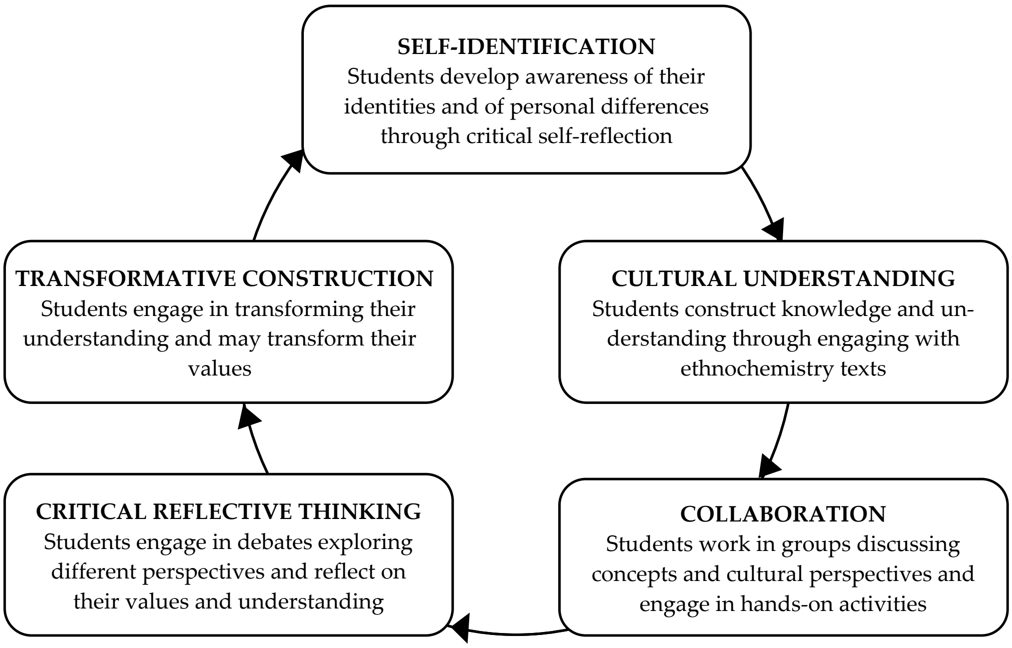

Figure 2. The culturally responsive transformative teaching (CRTT) model in chemistry learning [24].

In the initial self-identification stage, students explored their cultural identities by responding to questions about their cultural backgrounds, both individually and then by sharing with others. The teacher divided the students into groups based on diversity in their achievement levels and cultural backgrounds.

In the cultural understanding stage, the teacher integrated cultural concepts and chemistry learning content through an ethnochemistry text. Students worked in small groups to analyze the ethnochemistry text and engaged in hands-on, inquiry-based, chemistry activities. This collaboration was informed by social constructivism and was aimed at helping students develop an appreciation of the value of cooperation and a sense of acceptance of (culturally different) others.

In the fourth stage, the teacher shaped the learning process in the form of a whole class debate on issues related to the ethnochemistry text. Through the structured debate, students were challenged to deepen their knowledge in order to be able to express their opinions from various points of view and develop their critical thinking skills.

In the final stage, students constructed their understanding and reflected critically on their values based on their CRTT learning experience. Table 1 provides a summary of the four ethnochemistry texts and their link to chemistry concepts.

Table 1. Ethnochemistry texts linked to chemistry curriculum content.

Ethnochem. Text	Chemistry Topic	Cultural Description	Chemistry Concept
CHS—Banten Province			
Coconut milk in a typical Tangerang city 'mie laksa'	Colloid	Mie laksa is a culinary dish in Chinese and Malay culture that continues to experience development to suit the Indonesian tongue. Tangerang's typical laksa noodles are made from boiled white rice and then sprinkled with celery leaves, drenched in thick yellow sauce, and garnished with chicken broth, grilled chicken, boiled eggs, tofu, or potato curry. Coconut milk is a thickening agent used in cooking laksa sauce.	Coconut milk is a natural white milky oil-in-water emulsion extracted from the endosperm of ripe coconuts. Freshly extracted coconut milk is a relatively stable emulsion. They are naturally stabilized by coconut proteins, namely globulin and albumin, and the presence of phospholipid emulsifiers. Some of the proteins in the coconut milk aqueous phase interact with the fat lumps and act as emulsifiers by covering the surface. At too high a temperature and a long storage period, the protein in coconut milk will be degraded, which leads to a reduced ability to stabilize fat globules. As a result, instability occurs, which is characterized by coagulation and separation in the emulsion phase: a water-rich phase (skim) at the bottom and an oil-rich phase (cream) at the top.
CSS—West Java Province			
'Ngukus' the tradition of burning frankincense	Organic compound and its derivatives	This text discusses the Ngukus tradition among the Sundanese people. In Sundanese culture, Ngukus means "the activity of burning incense that accompanies certain rituals". Ngukus, generally, is conducted at the start of rituals, such as thanksgiving and prayers. The functions of burning incense include: scenting the room, repelling mosquitoes, increasing concentration when meditating.	Frankincense is the dried sap of the incense tree. One of the ingredients is cinnamic acid, which is an organic acid that has a double bond ($C_6H_5CH{=}HCOOOH$). Cinnamic acid can exist in the form of free or bound acids, as esters in essential oils, balsam resins, and in the leaves of frankincense trees.
PIS—Bangka Belitung Province			
Rusip typical Bangka	Acids and bases	Rusip is a fermented fish product from southern Sumatra and Bangka Island. Rusip is made from anchovies, which are fermented with 10–25% salt and around 10% palm sugar, based on the weight of the fish, and then put in a container and closed tightly. After two weeks of curing, the anaerobic fermentation process by lactic acid bacteria and microbes has produced amino acids from the protein in the fish and reduced the fat content in fresh fish.	Decomposition by lactic acid bacteria ($C_3H_6O_3$) can lower the pH in the range of 5–6, so that it not only adds flavor to food but also preserves it. The presence of salt is also useful. Besides being a flavor enhancer, it also inhibits spoilage.

Table 1. *Cont.*

Ethnochem. Text	Chemistry Topic	Cultural Description	Chemistry Concept
MPS—South Sumatra Province			
Cuko pempek	Electrolytes and non-electrolytes	Pempek is a typical Palembang food made from finely ground fish mixed with starch or sago flour and a composition of several other ingredients such as eggs, crushed garlic, and salt. Pempek is usually served with a dark brown sauce called cuko, which has a sour, sweet, and spicy taste with a distinctive spice aroma. Tamarind is a source of acid used in the manufacture of cuko pempek.	The sour taste comes from hydronium ions (H_3O^+) released by organic acids and acetic acid in vinegar. The release of hydronium ions causes an increase in the conductivity of the vinegar solution. The composition of the acids and ions in the cuko solution is refreshing when consumed because humans need electrolytes.

3.2. Data Generation

Qualitative data were generated by means of classroom observations, students' reflective journal entries, and semi-structured interviews with students. In conducting classroom observations of the teacher–student and student–student interactions, the researcher (second author) was assisted by two observers, the chemistry teachers in the partner schools. This method helped to generate an overall picture of the CRTT model implementation and its role in educating students for cultural sustainability. To reveal students' individual learning experiences, they were directed to respond in their reflective journals to questions designed to explore their engagement in cultural sustainability and any learning difficulties they might have experienced. The following are examples of the reflective journal questions:

- Where do you come from, do you know about your regional culture and the meaning behind it?
- Give your opinion about learning chemistry today! Are you getting better at understanding about the interrelationships between the chemistry concepts you are studying and your local culture?
- How would you respond if your friends in the group had a different opinion or cultural perspective than you?

Semi-structured interviews were conducted to explore more deeply the issues related to the learning experience and the development of students' chemical understanding and their cultural sustainability engagement. The following are examples of the interview questions:

- After gaining CRTT learning experiences, has it enhanced your motivation to study chemistry?
- From your point of view, what is your role as the younger generation in maintaining cultural sustainability?
- What challenges did you face in this culture-based chemistry learning and how did you respond to them?
- Based on the ethnochemistry text that you studied, which components of the cultural product are included in the categories of strong electrolyte and weak electrolyte solutions? How can this be identified?

3.3. Data Trustworthiness and Analysis

Data were analyzed in-line with a constructivist grounded theory approach through thematic analysis [60], namely: (1) interviews were transcribed, (2) data were coded, (3) codes were categorized into themes and sub-themes, and (4) the findings were presented in narrative form. The researchers used this process to generate data-driven theory on the CRTT model implementation and its implications for engaging students in ethnochemistry learning for cultural sustainability.

To optimize the quality of the data generated during the study, thereby ensuring that the conclusions drawn could be justified epistemologically, the researchers enacted credibility criteria to enhance the trustworthiness [59] in-line with the interpretive nature of the study. These ethnographic methods included prolonged engagement, persistent observation, progressive subjectivity, and member checking [60]. Throughout the study, prolonged engagement was carried out to understand the research contexts, to explore the characteristics of learners in terms of their cultural backgrounds and academic achievements, and to monitor both the teachers' implementation of the CRTT model and the students' valuing of cultural sustainability. For each research site, two classroom observers conducted persistent observations of all the learning activities, thereby generating trustworthy and in-depth data on students' engagement in the learning process. Progressive subjectivity was implemented by the researchers to monitor their ongoing synthesis of the data sources, with reference to their meeting notes recorded while conducting school visits. Member checking of students was conducted by the researchers to ensure the accuracy of their interpretations, especially for the purpose of clarifying any ambiguous data.

4. Results and Discussion

4.1. Pedagogical Strategies for Engaging Students in Culturally Responsive Chemistry Learning

The cultural understanding stage in the CRTT model requires teachers to link the chemistry curriculum with local cultural practices. Hence, with a view to improving students' level of cultural knowledge, teachers invited students to develop a better understanding of their culture through a range of pedagogical strategies: (1) engaging with ethnochemistry texts aimed at deepening local cultural understanding and linked to the chemistry curriculum; (2) engaging in hands-on, inquiry-based chemistry activities linked to the cultural practice; (3) linking ethnochemistry content to everyday life through small-group discussions; and (4) engaging students in a structured whole-class debate using argumentation skills. The steps in the CRTT model (see Figure 2) were intended to encourage students' transformative knowledge construction and to enable them to reflect critically on their cultural values and understanding. It is these aspects of the CRTT model that make it a transformative learning model also suitable for learning chemistry content.

4.1.1. Ethnochemistry Texts

We were particularly interested in how students experienced working with these texts. During our observations we noted that: "Students are enthusiastic when the teacher engages them in learning by presenting ethnochemistry texts. They learn many new things, and even when the teacher asks them to write learning reflections at the end of class students do not hesitate to express that studying chemistry while getting to know culture is fun for them" (Classroom Observation, PIS, 21 January 2020). A statement from Fatimah, a female PIS student, confirmed the observation by stating: ''The ethnochemistry text really helped broaden my horizons on the local culture and the chemistry perspective on it, and made learning chemistry a lot of fun" (Fatimah interview, PIS, 21 January 2021). Budi, a CSS male student, in his journal seemed to agree with Fatimah when he wrote that, "The ethnochemistry text is very useful for me to know various local traditions, reading them is very enjoyable because it's like reading stories" (Budi's Reflective Journal, CSS, 20 January 2020). Pointing to the direct relevance of these texts to students' lives, Ade, a male PIS student, explained that, "[. . .] through ethnochemistry texts, it provides clear evidence that the concept of acid and base is closely related to our lives, the most special, the example raised is an endemic fruit from Bangka Belitung (jeruk kunci)" (Ade's Reflective Journal, PIS, 14 January 2020). For Ade, ethnochemistry texts can serve as a medium for contextualizing chemical concepts in everyday life.

These student remarks strongly suggest that the integration of ethnochemistry texts can help increase motivation to learn new things related to exploring cultural practices in interesting ways. Drawing on cultural knowledge and real-life experience can give students the opportunity to construct their knowledge by being directly involved in the learning process.

4.1.2. Small-Group Discussions

Traditionally, most mainstream chemistry classes in Indonesia are conducted in a teacher-centred, direct-instruction style. Therefore, engaging students in active, collaborative, student-driven learning comes with its own challenges, mostly linked with students' initial reluctance to speak up. Nevertheless, our research indicates that one of the most engaging aspects of this new type of chemistry learning, according to Putri, a sociable student from CHS, were the small-group discussions, "I liked having discussions with a group of friends about the [chemical] components and how to cook our typical food. We then related [the discussion] to the colloid concept that we were studying" (Putri's Reflective Journal, CHS, 31 January 2020).

Chemistry learning in small-group settings seemed to encourage students to become more critically aware and careful in expressing their opinions. During our observations we noted that students were enthusiastic and skilful in expressing their ideas and thoughts, and they could also be critical, for example, when arguing about the impact of consuming rusip, a fermented food containing fish (anchovies), salt, and palm sugar. During their discussions students answered questions by linking several fields of science (Classroom Observation, PIS, 29 January 2020).

Peer social interaction promoted through small-group discussions facilitates students' ability to engage in positive interactions, which directly impacts their learning motivation [61,62]. Agus, a male PIS student wrote, in his journal that, "I got to know my classmates better because I was in groups with people I rarely talked to" (Agus's Reflective Journal, PIS, 16 January 2020). In a similar vein, Dewi, a female PIS student, outlined the benefits of group learning, particularly for groups with diverse cultural backgrounds, "I think it is more effective because [we] can share information and opinions and practice cooperation and communication. I also don't mind being divided into groups based on culturally diverse backgrounds. [Like this] we can have more positive interactions" (Interview Dewi, PIS, 30 January 2020). Fatimah, another female PIS student, seemed to concur with Dewi, emphasizing the benefits of collaborative learning, "I think group study is fun and useful because we can ask our friends. Sometimes when we study alone, it feels awkward to ask friends. Still, by working in groups, we are given space to communicate and ask questions so that all members understand the chemistry concepts being studied better" (Fatimah Interview, PIS, 30 January 2020). Lestari, a female CHS student, added that she likes, "[...] discussing the connection between the chemistry concept and Tangerang culture with my peers. We can exchange opinions with each other, respect others, and we are also trained to think before we speak. So what we are saying has a clear basis" (Lestari's Reflective Journal, CHS, 7 February 2020).

Despite most students not being used to small-group discussions, the differences in cultural backgrounds, learning styles, and student achievement encouraged students to practice respecting each other in expressing their opinions to achieve group conception.

4.1.3. Whole-Class Debate

Debate is a structured pedagogical strategy involving the whole class, organized into teams for the purpose of exploring a variety of perspectives and reflecting on values and understanding [13]. It is the culmination of all learning experiences, where students have to apply and evaluate their knowledge before synthesizing a suitable response.

Budi and Hartono, two male CSS students explained that the debates encouraged them to develop deep understanding so that they could respond quickly to opposing teams and also how to behave respectfully, "When debates take place between teams, competitive attitudes and cooperation between team members increase. Each student is required to present arguments slowly—not in a hurry—and also learn to be patient when receiving objections from other teams. In addition, we are required to respond and think critically when responding to arguments from the opposing party (Budi).” Hartono added that, “during the debate, each student is required to focus on listening to the arguments put forward by the opposing team. Apart from this, they have to respect each other's different views” (Budi and Hartono Student Interview, CSS, 3 February 2021).

Similar to small-group discussions, debates seem to have been viewed positively as expressed by Ade, a male PIS student, “today's debate about Rusip was very exciting because I could present my argument and listen to other arguments. I have the most fun during debates because my ability to speak, think, and respond is being tested during debates and that builds my understanding” (Ade's Reflective Journal, PIS, 4 February 2020). Hartono of CSS seems to support Ade's sentiment, “During the debate, we are required to have a positive attitude towards listening, delivering and responding to argument. Each one of us has to focus on listening to the arguments put forward by the opposing team” (Hartono Interview, CSS, 3 February 2020).

Hence, the competitive nature of the debate seems to have demonstrated to students the necessity of listening respectfully before responding competently. Indah, a female PIS student added that the attitude of mutual respect contributed positively to the cohesiveness of her group, “I think today's learning was better than before. During the debate, our group became more cohesive. Everyone could give their own opinion, and we learned to respect each other. So the debate ran smoothly” (Indah's Reflective Journal, PIS, 4 February 2020). We were able to confirm Indah's assessment of the quality of the social interactions during the debate. In our observation notes we wrote, “Students are enthusiastic about expressing their opinions. They listen carefully when someone in their group conveys their views” (Classroom Observation, CHS, 18 January 2020).

The results of our inquiry indicate that during the whole-class debate students were challenged to develop the skills to listen carefully before expressing their opinions and defending their arguments respectfully. In addition, we were able to identify that students enjoyed social interactions and the group cohesiveness improved.

4.2. Learning Chemistry Content through CRTT

Culturally responsive transformative teaching aims to foster concrete, in-depth, and locally relevant chemistry learning. The following examples were chosen because they demonstrate the links between students' cultural chemistry learning and links to students' everyday lives.

4.2.1. The Chemistry of Dodol

Dodol is a traditional sweet and soft sugar palm confection, typical in Indonesian cuisine. The main ingredients are coconut milk, palm sugar, and glutinous rice flour. There are many local recipes and techniques for making dodol that require many hours of cooking and stirring to create a colloidal suspension, whereby insoluble particles are suspended throughout another substance. During our observation we found that that Joko, a male student from CHS, was able to identify and describe the concept of colloids in relation to making dodol. We noted also that Joko was able to correctly create a colloidal mixture during the dodol mixing process. He could describe the colloidal properties of the solution, where glutinous rice flour and sugar formed the dispersed particles and coconut milk was the dispersion liquid (Classroom Observation, CHS, 7 February 2020).

4.2.2. The Chemistry of Pempek

Pempek is a traditional Indonesian fishcake and is typical of Palembang in south Sumatera with (potentially) Chinese origins. It seems to have been a method for preserving fish. Pempek dough is made up from fish, water, salt, and flour, which is shaped into dumplings that are cooked in water and stored before being fried just before consumption. The accompanying sauce, called cuko, is made of palm sugar, spices, vinegar, salt, and water. During learning about pempek, students conducted experiments on the electrical conductivity of various sample solutions, one of which was vinegar, which is commonly found in the sauce that comes with traditional pempeks. During our observations, students seemed to understand that vinegar is an example of a weak electrolyte solution, based on the experiments they carried out testing electrolyte solutions with electrodes. Many were able to explain that if a solution is an electrolyte this can be observed by checking the electrodes: in a strong electrolyte solution there will be many bubbles and the attached lamp will light up brightly. In a weak electrolyte solution, by contrast, there will be very few bubbles and the light will either be dim or go out altogether. Non-electrolyte solutions do not show either reaction (Classroom Observation, MPS, 20 February 2021).

Dwi, a male MPS student explained that, "vinegar contains acetic acid [making it] a weak electrolyte solution. [The formula is] CH_3COOH meaning it has a covalent bond between non-metallic substances" (Reflective Journal of Student 12, MPS, 22 February 2021). Similarly, Indah, a female MPS student, recognized that, "chemistry and culture are related. For example, Cuko contains acetic acid like in Pindang Sauce which also contains acid from tamarind. With Batik, during the process of making it, caustic soda is used" (Reflective Journal of Student 18, MPS, 22 February 2022). Indah seems to have clearly understood the links between chemistry and everyday life, since she was also able to provide additional examples. Pindang sauce, for example, originates from Palembang, but is also used in Java and Kalimantan. It is an acidic solution used for cooking and for preserving fish.

4.2.3. The Chemistry of Lahang

Lahang is a sweet drink traditionally associated with west Java. It is made from the sap of sugar palms (Aren) and requires a certain skill set to harvest and produce the drink, which is traditionally sold in bamboo vessels. Hasan, a male student from CSS, explained in his interview, "I became curious about the sugar palm sap which has almost disappeared [from our culture] because of the tendency of sugar palm sap to ferment easily, which eventually produces wine due to direct contact with air" (Interview of Hasan, CSS, 3 February 2020). Fermentation is a problem when religion forbids the consumption of alcoholic drinks. Such is the case in Java, whereas in neighboring Bali people traditionally allow lahang to ferment and become alcoholic, as Balinese religion traditionally does not limit the consumption of alcohol. In the class at CSS we observed the following exchange between the teacher and Hasan:

> *Teacher: Speaking of our local culture—'Lahang'—do you have any ideas how it could be made more widely known to West Javan citizens?*
>
> *Hasan: From the video I watched there are just a few people who sell Lahang, and hardly anybody knows how to tap [the sugarpalm sap] and make Lahang. This tradition should be shared with the younger generation by making use of improved technology. Young Indonesians could market it more extensively through Marketplace and innovate by using bottles. Alternatively, they could make [Lahang] longlife [so that it does not] ferment easily (Classroom Observation, CSS, 3 February 2020).*

This conversation highlights an interesting cultural ethical dilemma linked to the consumption of lahang which, if fermented, is problematic for people who, for religious reasons, cannot consume alcoholic drinks. This may have contributed to the near disappearance of this ancient cultural practice and knowledge in Java. Based on his learning, Hasan seems to be striving to revive the old tradition and spread the word about it amongst the population while, at the same time, trying to keep the lahang alcohol-free, thus making it an acceptable drink for religious people.

Dodol, pempek, and lahang are examples that highlight that CRTT appears to have enabled the students to connect learning about culture and chemistry concepts and apply them to their everyday lives.

4.3. Transformative Learning through CRTT in the Context of Chemistry Learning

Transformative learning encourages learners to reflect critically on their taken-for-granted assumptions, values, and beliefs. Reported changes in attitudes based on new insights are indicators that transformative learning has taken place. During our observations, we found evidence suggesting that whilst learning chemistry students also looked back at history which, in turn, encouraged them to take on responsibility for preserving their culture. The following dialogue between the teacher and Mawar, a female CSS student, reflects her concern for preserving her culture and examining local cultural attitudes through a scientific lens:

> *Mawar: This learning has changed my attitude to care more about preserving local culture.*
>
> *Teacher: Why do you think that preserving culture is important?*
>
> *Mawar: [...] because there are many benefits, and it is our [cultural] wealth that we must preserve. Meanwhile, Indonesian people are more interested in myths and beliefs, meaning that cultural learning through the lens of Science is not commonly done" (Mawar Interview, CSS, 20 February 2020).*

We noted in our observation records that, "Students seemed to understand that culture needed to be preserved because 'our heroes of the past' have struggled to preserve culture since ancient times—now it is up to all of us to protect and preserve culture. If culture is not preserved the impact will be visible from the outside and culture can disappear" (Classroom Observation, MPS, 23 February 2021). Some students, like Hasan, a male student from CSS, appeared to recognise the importance of keeping an open mind whilst maintaining excellent knowledge of their own culture, as evidenced in this dialogue between teacher and student:

> *Teacher: [it appears that] today culture has been greatly displaced by foreign cultures: today's children know more about foreign cultures than their own. What do you think?*
>
> *Hasan: ... we need to know other countries' culture so we have broad knowlege, but the important point is that we have to learn about our local culture in great depth*
>
> *(Hasan Interview, CSS, 3 February 2020).*

In addition to having an opportunity to study culture and chemistry at the same time, there appears to have been an additional benefit to those students who were not indigenous to the local area, such as Ratih, a female MPS student, who explained, "[...] since I am not native to Palembang, learning chemistry with a cultural approach helps me to recognize and adapt to the culture here" (Reflective Journal of Ratih, MPS, 20 February 2021).

4.4. Students' Experiences of CRTT in Chemistry Learning

Since we had set out to investigate if CRTT had the potential to enhance student engagement in chemistry learning through integrating ethnochemistry issues, we needed to explore students' experiences with the CRTT implementation.

Widya, a female student from MPS, seemed to confirm the efficacy of the CRTT model for engaging students in chemistry learning by stating that, "In my opinion, cultural integration really helps me understand chemistry concepts. I can learn chemistry in a fun way and participate in preserving my regional culture" (Reflective Journal Widya, MPS, 20 February 2021). Setiawan and Agung, two male MPS students, concurred with Widya in saying that, "Learning chemistry related to culture and daily life adds to my experience and makes me more motivated for the next topic, especially coupled with experimental activities" (Interview of Setiawan and Agung, MPS, 22 February 2021). Budi, a male student from CSS, reported that he was, "[...] very enthusiastic because I am [now] motivated to find new information about chemistry associated with culture" (Budi's Reflective Journal, CSS, 3 February 2020). This sentiment was supported by Eka, a female CSS student, who wrote in her journal that, "[...] this learning is interesting, because it makes students more active, adds insight, [makes me] think critically and know more about culture" (Eka's Reflective Journal, CSS, 3 February 2020). Eka's statement seems to highlight well her engagement in transformative learning aspects, which was also reflected by Nurul, a female PIS student, who wrote that, "[...] learning chemistry concepts in a new way can develop [my] thinking to find out the meaning and connection to chemistry. Learning chemistry that is linked to this [local] culture encourages us to be more curious about our culture. It was fun for me!" (Nurul's Reflective Journal, PIS, 4 February 2020). Putra, a male MPS student, summarized well what many students reported in their interviews and in their reflective journals, "It was very engaging, I become more knowledgeable about my culture in terms of chemical concepts" (Interview of Student 10, MPS, 10 February 2021).

Statements like these highlight that, through CRTT, students can achieve academic goals, develop cultural awareness, and construct new cultural and chemistry knowledge based on their learning experiences [19,63].

5. Conclusions

The results of this mini-ethnographic research indicate that ethnochemistry learning based on the CRTT model and implemented in Indonesian cultural contexts has the potential to engage secondary chemistry students in exploring interrelationships between the chemistry curriculum content, local cultural practices, and examples of chemistry in everyday life. Through the CRTT model, students experienced enhanced meaningful chemistry learning that was different from their standard chemistry classes in that it combined cultural learning with inquiry-based, student-driven, and collaborative pedagogical approaches.

Research findings from four schools in four provinces in Indonesia demonstrate that the CRTT model can facilitate students' engagement in culture-based chemistry learning. Self-identification allows students to explore their cultural identity and reflect on how well they know their culture. A deepened understanding of culture through the lens of chemistry was facilitated through integrating ethnochemistry texts combined with hands-on activities, which motivated students to learn more about culture and the practices therein. Opportunities to exchange understanding and perspectives though collaborative learning in small groups representing cultural diversity positively impacted social interaction, learning motivation, and students' critical and analytical thinking abilities. The diverse cultural backgrounds seem to have encouraged acceptance of difference as the basis for mutual respect, when conveying to and receiving from other students' opinions and beliefs that may be different. Furthermore, learning experiences during the four CRTT stages seem to have encouraged students to transform some of their understanding.

In particular, the study illustrated that students were involved in cultural identity reflection, engaged in cultural-based chemistry learning, explored cultural heritage through a chemistry lens, applied social etiquette and ethics, and developed cultural heritage preservation awareness, which are all important outcomes in the context of cultural sustainability education. Thus, the results highlight the potential of the CRTT model for learning relevant chemistry concepts and the related scientific language through an ethnochemistry approach, with a focus on preserving indigenous, ancestral knowledge for future generations.

6. Limitation and Recommendations

As this study was an interpretive mini-ethnography inquiry consisting of four case studies involving senior high schools in four provinces in Indonesia, the in-depth findings are specific to the local contexts and cannot be generalized. However, as this research has demonstrated, the CRTT model, when conducted in a chemistry education context, has the potential to provide concrete, in-depth, and locally relevant chemistry learning by integrating ethnochemistry texts and related study materials. Thus, we may infer that students in other cultural contexts outside of Indonesia might also successfully engage in ethnochemistry learning that promotes cultural sustainability if the chemistry curriculum is adapted in line with the CRTT model. In the future, a broader study involving other cultural contexts could be conducted.

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References

1. BPS. *Statistik Sosial Budaya 2021*; Badan Pusat Statistik: Jakarta, Indonesia, 2022.
2. Santos, R.I. Girls, gold, and gods: Perverted individualism and heightened secularism in O'Neill's Desire under the Elms. *Comp. Lit. East West* **2022**, *6*, 105–115. [CrossRef]
3. Kumar, R.; Zusho, A.; Bondie, R. Weaving cultural relevance and achievement motivation into inclusive classroom cultures. *Educ. Psychol.* **2018**, *53*, 78–96. [CrossRef]
4. Chinn, P.W. Developing teachers' place-based and culture-based pedagogical content knowledge and agency. In *Second International Handbook of Science Education*; Fraser, B.J., Tobin, K.G., McRobbie, C.J., Eds.; Springer: Dordrecht, The Netherlands, 2012; pp. 323–334. [CrossRef]
5. Nutti, Y.J. Decolonizing indigenous teaching: Renewing actions through a critical utopian action research framework. *Action Res.* **2018**, *16*, 82–104. [CrossRef]
6. Kana'iaupuni, S.; Ledward, B.; Jensen, U. *Culture-Based Education and Its Relationship to Student Outcomes*; Kamehameha Schools, Research, & Evaluation: Honolulu, HI, USA, 2010.
7. Ladson-Billings, G. Toward a theory of culturally relevant pedagogy. *Am. Educ. Res. J.* **1995**, *32*, 465–491. [CrossRef]
8. Lee, J.S.; Anderson, K.T. Negotiating linguistic and cultural identities: Theorizing and constructing opportunities and risks in education. *Rev. Res. Educ.* **2009**, *33*, 181–211. [CrossRef]
9. Hernandez, C.M.; Morales, A.R.; Shroyer, M.G. The Development of a model of culturally responsive science and mathematics teaching. *Cult. Stud. Sci. Educ.* **2013**, *8*, 803–820. [CrossRef]
10. Brown, D.F. Urban teachers' professed classroom management strategies. *Urban Educ.* **2004**, *39*, 266–289. [CrossRef]
11. Taylor, P.C.; Luitel, B.C. *Research as Transformative Learning for Sustainable Futures: Glocal Voices and Visions*; Brill-Sense: Leiden, The Netherlands, 2019.
12. Taylor, E.; Taylor, P.C. *Transformative STEAM Education for Sustainable Development: International Perspectives and Practices*; Brill: Leiden, The Netherlands, 2022.
13. Rahmawati, Y.; Ridwan, A.; Rahman, A.; Kurniadewi, F. Chemistry Students' Identity Empowerment through Etnochemistry in Culturally Responsive Transformative Teaching (CRTT). *J. Phys. Conf. Ser.* **2019**, *1156*, 012032. [CrossRef]
14. Goldberg, D. *Schaum's Outline of Theory and Problems of Beginning Chemistry*; McGraw-Hill: New York, NY, USA, 2005.
15. Gomollón-Bel, F.; García-Martínez, J. Emerging chemistry technologies for a better world. *Nat. Chem.* **2022**, *14*, 113–114. [CrossRef] [PubMed]
16. Eilks, I.; Hofstein, A. *Relevant Chemistry Education: From Theory to Practice*; Springer: Dordrecht, The Netherlands, 2015.
17. Nelson, P. Teaching chemistry progressively: From substances, to atoms and molecules, to electrons and nuclei. *Chem. Educ. Res. Pr.* **2002**, *3*, 215–228. [CrossRef]
18. Childs, P.E.; Hayes, S.; O'dwyer, A. Chemistry and everyday life: Relating secondary school chemistry to the current and future lives of students. In *Relevant Chemistry Education*; Eilks, I., Hofstein, A., Eds.; SensePublishers: Rotterdam, The Netherlands, 2015; pp. 23–44. [CrossRef]
19. Rahmawati, Y.; Ridwan, A.; Nurbaity. Should we learn culture in chemistry classroom? integration ethnochemistry in culturally responsive teaching. In *AIP Conference Proceedings*; AIP Publishing LLC: Melville, NY, USA, 2017; p. 030009. [CrossRef]
20. Chittleborough, G. The Role of Teaching Models and Chemical Representations in Developing Students' Mental Models of Chemical Phenomena. Ph.D. Dissertation, Curtin University of Technology, Bentley, WA, Australia, 2004.
21. Badea, E. Chemistry for cultural heritage: Connecting past and future. *Herit. Sci.* **2019**, *7*, 99. [CrossRef]
22. Sudarmin; Febu, R.; Nuswowati, M.; Sumarni, W. Development of ethnoscience approach in the module theme substance additives to improve the cognitive learning outcome and student's entrepreneurship. *J. Phys. Conf. Ser.* **2017**, *824*, 012024. [CrossRef]

23. Asfina, R.; Ovilia, R. Be proud of indonesian cultural heritage richness and be alert of its preservation effort in the global world. *Humanus* **2017**, *15*, 195. [CrossRef]
24. Rahmawati, Y.; Ridwan, A. Empowering students' chemistry learning: The integration of ethnochemistry in culturally responsive teaching. *Chem. Bulg. J. Sci. Educ.* **2017**, *26*, 813–830.
25. Battiste, M. *Indigenous Knowledge and Pedagogy in First Nations Education: A Literature Review with Recommendations*; Indian and Northern Affairs Canada: Ottawa, ON, Canada, 2002.
26. Ruheza, S.; Matte, S.; Chingonikaya, E.; Kilugwe, Z. Integration of the indigenous knowledge system (iks) for sustainable management and use of biodiversity in South Nguru Mountain Forest, Tanzania: The influence of socio-economic and political factors. *J. Sustain. Dev. Afr.* **2013**, *15*, 94–114.
27. Ward, J. Grounding Curriculum and Pedagogies in Indigenous Knowledge and Indigenous Knowledge Systems. Master's Thesis, Athabasca University, Athabasca, AB, Canada, 2010.
28. Throsby, D.; Petetskaya, E. Sustainability concepts in indigenous and non-indigenous cultures. *Int. J. Cult. Prop.* **2016**, *23*, 119–140. [CrossRef]
29. Acton, R.; Salter, P.; Lenoy, M.; Stevenson, R. Conversations on cultural sustainability: Stimuli for embedding indigenous knowledges and ways of being into curriculum. *High. Educ. Res. Dev.* **2017**, *36*, 1311–1325. [CrossRef]
30. UNESCO. *Investing in Cultural Diversity and Intercultural Dialogue Executive Summary UNESCO World Report*; UNESCO: Paris, France, 2009.
31. Van den Branden, K. Sustainable education: Basic principles and strategic recommendations. *Sch. Eff. Sch. Improv.* **2012**, *23*, 285–304. [CrossRef]
32. Axelsson, R.; Angelstam, P.; Degerman, E.; Teitelbaum, S.; Andersson, K.; Elbakidze, M.; Drotz, M.K. Social and cultural sustainability: Criteria, indicators, verifier variables for measurement and maps for visualization to support planning. *Ambio* **2013**, *42*, 215–228. [CrossRef]
33. Kagan, S. *Art and Sustainability: Connecting Patterns for a Culture of Complexity*; Transcript Verlag: Bielefeld, Germany, 2007.
34. Soini, K.; Birkeland, I. Exploring the scientific discourse on cultural sustainability. *Geoforum* **2014**, *51*, 213–223. [CrossRef]
35. Eriksen, T.H. *Small Places, Large Issues*; Pluto Press: London, UK, 2001.
36. Hastrup, K. Kultur som analytisk begreb. In *Fortolkningens Forløb i Antropologien*; Hastrup, K., Ramløv, K., Eds.; Akademisk Forlag: Copenhagen, Denmark, 1989.
37. Finlayson, M. Cultural sustainability of african canadian heritage: Engaging students in learning, the past, the present and the future. *Improv. Sch.* **2015**, *18*, 142–156. [CrossRef]
38. United Nations. *Report of the World Commission on Environment and Development: Our Common Future*; United Nations: Oslo, Norway, 1987.
39. Soini, K.; Dessein, J. Culture-sustainability relation: Towards a conceptual framework. *Sustainability* **2016**, *8*, 167. [CrossRef]
40. Laine, M. Culture in sustainability—Defining cultural sustainability in education. *Discourse Commun. Sustain. Educ.* **2016**, *7*, 52–67. [CrossRef]
41. Roy, S. Chemistry in our daily life: Preliminary information. *Int. J. Home* **2016**, *2*, 361–366.
42. Yager, R.E. The constructivist learning model: Towards real reform in science education. *Sci. Teach.* **1991**, *6*, 52–57.
43. Chen, Y.; Techawitthayachinda, R. Developing Deep Learning in Science Classrooms: Tactics to Manage Epistemic Uncertainty during Whole-class Discussion. *J. Res. Sci. Teach.* **2021**, *58*, 1083–1116. [CrossRef]
44. Dalgety, J.; Coll, R.K.; Jones, A. Development of chemistry attitudes and experiences questionnaire (CAEQ). *J. Res. Sci. Teach.* **2003**, *40*, 649–668. [CrossRef]
45. Treagust, D.; Nieswandt, M.; Duit, R. Sources of students' difficulties in learning chemistry. *Educ. Química* **2000**, *11*, 228–235. [CrossRef]
46. Rüschenpöhler, L.; Markic, S. Secondary School Students' Chemistry Self-Concepts: Gender and Culture, and the Impact of Chemistry Self-Concept on Learning Behaviour. *Chem. Educ. Res. Pract.* **2020**, *21*, 209–219. [CrossRef]
47. Bonner, P.J.; Warren, S.R.; Jiang, Y.H. Voices from Urban Classrooms: Teachers' Perceptions on Instructing Diverse Students and Using Culturally Responsive Teaching. *Educ. Urban Soc.* **2018**, *50*, 697–726. [CrossRef]
48. Gay, G. Teaching to and through cultural diversity. *Curric. Inq.* **2013**, *43*, 48–70. [CrossRef]
49. Gay, G. Preparing for culturally responsive teaching. *J. Teach. Educ.* **2002**, *53*, 106–116. [CrossRef]
50. Shevalier, R.; McKenzie, B.A. Culturally responsive teaching as an ethics- and care-based approach to urban education. *Urban Educ.* **2012**, *47*, 1086–1105. [CrossRef]
51. Abacioglu, C.S.; Volman, M.; Fischer, A.H. Teachers' multicultural attitudes and perspective taking abilities as factors in culturally responsive teaching. *Br. J. Educ. Psychol.* **2020**, *90*, 736–752. [CrossRef]
52. Cuseo, J. *Cooperative/Collaborative Structures Explicitly Designed to Promote Positive Interdependence among Group Members*; Ilinois State University, Office of Academic Technologies, Center for Teaching, Learning, and Technology: Normal, IL, USA, 2000.
53. Harriott, W.A.; Martin, S.S. Using culturally responsive activities to promote social competence and classroom community. *Teach. Except. Child.* **2004**, *37*, 48–54. [CrossRef]
54. Johnson, D.W.; Johnson, R. Cooperative learning, values, and culturally plural classrooms. In *Education, Culture and Values: Classroom Issues: Practice, Pedagogy and Curriculum*; Leicester, M., Modgil, C., Modgil, S., Eds.; Falmer Press: New York, NY, USA, 2000; Volume 3, pp. 18–36.

55. Mezirow, J. *Transformative Dimensions of Adult Learning*; Jossey-Bass: San Fransisco, CA, USA, 1991.
56. Taylor, E.W.; Cranton, P. *The Handbook of Transformative Learning: Theory, Research, and Practice*; Jossey-Bass: San Fransisco, CA, USA, 2012.
57. Taylor, P.C. Transformative science education. In *Encyclopedia of Science Education*; Springer: Dordrecht, The Netherlands, 2015.
58. Fusch, P.I.; Fusch, G.E.; Ness, L.R. How to conduct a mini-ethnographic case study: A guide for novice researchers. *Qual. Rep.* **2017**, *22*, 923–941. [CrossRef]
59. Guba, E.G.; Lincoln, Y. *Fourth Generation Evaluation*; SAGE Publications: Newbury Park, CA, USA, 1989.
60. Miles, M.; Huberman, A. Qualitative data analysis: An expanded sourcebook. *J. Environ. Psychol.* **1994**, *14*, 336–337. [CrossRef]
61. Kong, S.C.; Song, Y. An experience of personalized learning hub initiative embedding BYOD for reflective engagement in higher education. *Comput. Educ.* **2015**, *88*, 227–240. [CrossRef]
62. Loes, C.N. The effect of collaborative learning on academic motivation. *Teach. Learn. Inq.* **2022**, *10*, 1–17. [CrossRef]
63. Taber, K.S. *Alternative Conception in Chemistry: Prevention, Diagnosis, and Cure?* The Royal Society of Chemistry: London, UK, 2002.