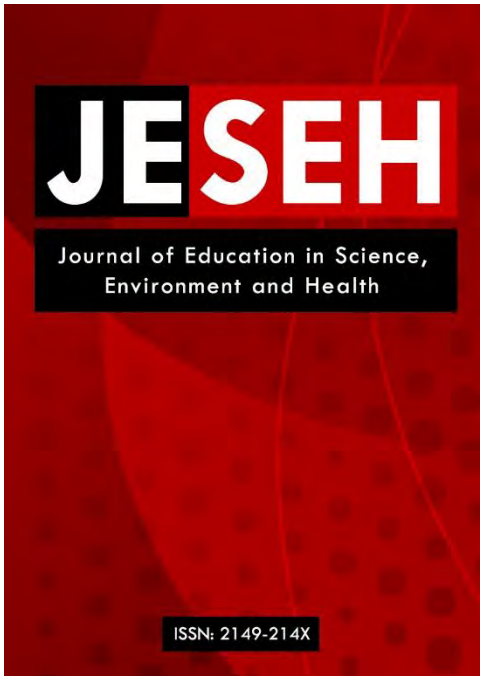

ISSN: 2149-214X

Journal of Education in Science, Environment and Health

www.jeseh.net

Exploring Pedagogical Strategies: Integrating 21st-Century Skills in Science Classrooms

Esty Haryani[1], William W. Cobern[2], Brandy Ann-Skjold Pleasants[2], Marcia K. Fetters[2]
[1]Ministry of Education and Culture (Indonesia)
[2]Western Michigan University

To cite this article:

Haryani, E., Cobern, W. W., Pleasants, B. A-S. & Fetters, M. (2024). Exploring pedagogical strategies: Integrating 21st-century skills in science classrooms. *Journal of Education in Science, Environment and Health (JESEH), 10*(2), 106-119. https://doi.org/10.55549/jeseh.697

JESEH
Journal of Education in Science, Environment and Health
Volume 10, Issue 2, 2024
https://doi.org/10.55549/jeseh.697

Exploring Pedagogical Strategies: Integrating 21st-Century Skills in Science Classrooms

Esty Haryani, William W. Cobern, Brandy Ann-Skjold Pleasants, Marcia K. Fetters

Article Info

Article History

Published:
01 April 2024

Received:
26 January 2024

Accepted:
21 March 2024

Keywords

21st-century skills
Pedagogical strategies
Science classrooms

Abstract

Developing 21st-century skills among students is crucial for their success in college, future careers, and civic engagement. These skills, commonly referred to as the 4Cs (creativity, critical thinking and problem-solving, communication, and collaboration), require teachers to provide tailored learning experiences. This study investigates the factors influencing teachers' selection of pedagogical strategies to foster the integration of the 4Cs, their approach to lesson planning, and the actual implementation of these plans in the classroom. In this qualitative study, three chemistry teachers, self-reporting moderate 4C implementation, participated. Data were gathered through semi-structured interviews, analysis of lesson plans, and classroom observations. The findings reveal that teachers take into account student characteristics and learning facility availability when designing 4C-integrated lesson plans. Influencing factors include student attributes, the science topic, and teachers' mastery of the chosen approach. Communication, collaboration, and critical thinking emerge as the most integrated skills, with interactive lectures being the predominant teaching method. The study discusses the implications of these findings for educators and curriculum development.

Introduction

Globalization is exerting pressure on educational systems to prioritize the preparation of students for active participation in public engagement and potential careers that demand advanced analytical skills (Boix Mansilla & Bughin, 2011; Bybee & Fuchs, 2006; Saavedra & Opfer, 2012; Trilling & Fadel, 2009). While the importance of developing creativity, critical thinking, problem-solving, communication, and collaboration skills in students has long been recognized, current global challenges necessitate a renewed focus on integrating these skills into the curriculum (Senechal, 2010).

In 2002, the Partnership for 21st Century Skills (P21) initiated the development of a framework for 21st Century Learning, highlighting 18 different skills essential for the modern era. Subsequently, education leaders, businesses, industries, and related groups collectively identified four specific skills as paramount—commonly known as the 4Cs: creativity, critical thinking and problem-solving skills, communication, and collaboration (The National Education Association, 2012).

According to the National Education Association (NEA, 2012), cultivating critical thinking involves the development of deeper analytical skills and thinking processes. The contemporary workplace places a premium on effective communication and teamwork, making it imperative for education to foster students' abilities to express thoughts clearly, articulate concepts, provide concise instructions, motivate others, and collaborate to achieve meaningful results.

The practical integration of 4C skills should become a routine aspect of everyday science classrooms. Teachers play a crucial role in this process by designing their instruction to seamlessly incorporate the 4Cs into core science lessons. Students must have regular opportunities to practice and master these skills while concurrently mastering the science content (The National Education Association, 2012). As suggested by the NEA (2012), integrating the 4Cs should not diminish the importance of content knowledge but rather enhance the understanding of content and improve the overall student learning experience.

Therefore, teachers face the challenge of selecting appropriate teaching approaches that underscore the integration of the 4Cs into science learning. The ensuing discussion will delve into a deeper understanding of these 4Cs.

Literature Review

The 4Cs

Creativity and Innovation

Creativity encompasses the capacity to generate, refine, analyze, and evaluate original concepts to optimize creative efforts. It involves thinking creatively, collaborating with others in a creative manner, and implementing innovations (Partnership For 21st Century Skills, 2009).

Critical Thinking and Problem Solving

Critical thinking is the ability to reason effectively, utilizing facts and arguments within systems of thinking to make decisions. It involves drawing conclusions based on the best interpretation of evidence, leading to well-informed decisions (Partnership For 21st Century Skills, 2009; The National Education Association, 2012).

Communication

Communication skills denote the capability to express ideas clearly through oral, written, and nonverbal means. Additionally, effective communication involves listening attentively and respectfully in diverse environments (Partnership For 21st Century Skills, 2009).

Collaboration

Collaboration is defined as the ability to work productively and respectfully with other group members, demonstrating flexibility and a willingness to aid and compromise to achieve team goals (Partnership For 21st Century Skills, 2009).

Teaching 4C into Science Classroom

Incorporating the 4Cs into science classrooms requires teachers to leverage various resources when designing lesson plans, modeling skills, and planning activities intentionally integrating the 4Cs. Teachers should explicitly explain and engage students in discussions about the skills to be addressed and practiced (Saavedra & Opfer, 2012). Additionally, they play a pivotal role in supervising, providing input, and encouraging students to focus on their skill development progress, recognizing it as an ongoing process (Oliver, 2016). Saavedra & Opfer's (2012) study on science learning advocates nine strategies for effectively teaching 21st-century skills, enhancing students' understanding of content knowledge while cultivating creativity, critical thinking, problem-solving, communication, and collaboration skills. These strategies include:

1. Exploring generative topics through both inductive and deductive reasoning, encouraging students to relate science concepts to their daily lives for relevance.
2. Facilitating learning through disciplines that allow students to acquire fundamental knowledge, apply it creatively to solve problems, and effectively communicate their findings.
3. Developing both lower and higher-order thinking skills by posing thought-provoking questions and assisting students' thinking with probing questions.
4. Promoting transfer of learning, enabling students to reflect on what they've learned and gain confidence in adapting knowledge to various circumstances.
5. Designing lessons that reinforce metacognition practices, allowing students to evaluate their thinking through activities like debates.
6. Addressing misconceptions directly and helping students establish scientific knowledge through modeling and explicit instructions.
7. Designing science instruction that fosters teamwork and peer learning.
8. Utilizing technology to support learning processes and enhance pedagogy, science content, and comprehension-based experiences.

In Indonesia, similar to other countries, the government has revised education standards to enhance the quality of education by focusing on student mastery learning and fostering 21st-century skills. The Indonesian Ministry of Education and Culture (MoEC) has implemented policies and launched teaching guides to assist teachers in facilitating learning, enabling students to develop skills in creativity and innovation, critical thinking and problem-solving, communication, collaboration, and self-confidence (Ariyana et al., 2018). MoEC regulation No 22 of 2016 on the Standard of Process for the implementation of Curriculum 2013 (C13) advocates learning models that integrate the 4Cs, including discovery/inquiry-based learning, Problem-Based Learning, and Project-Based Learning, among others.

The inclusion of 4C skills in the Indonesian national curriculum has sparked growing interest in studying 21st-century skills. This includes analyses of the 21st-century learning skills framework (Afandi et al., 2019; Erimurti, n.d.), reviews of literature on assessment for 21st-century learning skills (Winaryati, 2018), examinations of teaching strategies to cultivate the 4Cs (Priyatni & As'ari, 2019), investigations into teachers' priorities regarding 4C integration (Haryani et al., 2019), and explorations of teachers' perspectives on 4C integration (Ramdiah et al., 2019; Umiringtyas et al., 2019).While there exists a considerable body of literature on 21st-century skills and their integration into educational frameworks, few studies have delved into the practical implementation of the 4Cs within science classrooms. Notably, there is a dearth of research exploring the extent to which teachers have adopted Saavedra & Opfer's (2012) strategies for teaching the 4Cs. Additionally, limited research addresses the specific strategies employed by teachers in teaching the 4Cs. Recognizing the potential benefits of these teaching approaches in fostering student 4C development and acknowledging the pivotal role of science teachers in this integration, this study aims to comprehend how teachers bridge educational resources and the factors influencing their decisions to implement Indonesia's curriculum revision within actual chemistry classrooms by asking the following questions:

1. In what ways do teachers integrate the 4C skills into their science lessons?
2. What factors do teachers consider when developing a science lesson plan that emphasizes the integration of the 4Cs?
3. What explanations do teachers provide when selecting a particular teaching strategy for incorporating the 4Cs?
4. How do teachers evaluate and judge the appropriateness of their science lesson plans in terms of the integration of the 4Cs?

Method

Study Design

This study employed a case design to explore the factors influencing teachers' integration of the 4Cs into their teaching practices. Data collection involved a comprehensive approach, utilizing semi-structured interviews, classroom observations, field notes, and teacher lesson plans for triangulation (Yin, 2018). The diverse data sources aimed to achieve a "thick description" (p. 259) of the case under investigation, aligning with the research questions (Cresswell, 2013; Mertens, n.d.).

The case study design facilitated an in-depth understanding of teachers' real-life routines as they prepared 4Cs-integrated chemistry lesson plans and implemented them in the classroom. Interviews provided insights into teachers' opinions, experiences, and perspectives, while lesson plan data detailed the preparation process and described how the learning process would unfold. Classroom observations offered evidence of 4Cs integration within the teacher's context (Gustafsson, 2017), contributing to comprehensive descriptions of the case (Cresswell, 2013).

Participants

Three chemistry teachers from a public vocational high school in West Kalimantan, Indonesia, participated in this study. School data indicated that the institution had implemented a revision of the 2013 curriculum (C13 revision). Survey responses from these teachers self-reported moderate integration of the 4Cs into their science classroom instruction, making them suitable candidates for the study. These teachers had also attended professional development sessions related to 4C integration. Participants were requested to submit two chemistry lesson plans, undergo a 40-60 minute interview, and permit three classroom observations for each lesson plan across different classes. The characteristics of the participating teachers are outlined in Table 1.

Table 1. Teacher profile

Name (pseudonym)	Years of teaching	Highest education level	Professional certification
Mrs. Dewi	20	master	Yes, chemistry
Mrs. Ratna	10	bachelor	Yes, chemistry
Mr. Budi	10	bachelor	Yes, chemistry

Design and Procedure

The study involved interviewing and observing three chemistry teachers who willingly participated in the research. The observation schedule was aligned with the teachers' instructional plans, excluding sessions earmarked for testing. To gain insights into the teachers' planning experiences, including the factors influencing their decision to integrate the 4Cs into chemistry instructions, their chosen approaches, and how they assessed lessons, the three teachers underwent initial interviews lasting 40-60 minutes.

These interviews, conducted at the school and scheduled based on the teachers' convenience, were audio-recorded. Before the classroom observations, teachers submitted their lesson plans. Two teachers submitted two lesson plans each for a total of six classroom observations, while another teacher submitted three lesson plans for six classroom observations. The lesson plans were scrutinized to assess the teachers' intentions to integrate the 4Cs. Classroom observations aimed to gauge the extent to which teachers implemented their plans for 4C integration.

During observations, lesson plans were systematically examined to determine whether the 4Cs were mentioned in teaching objectives and integrated into core learning activities, remarks, and reflections. The objective was to assess how extensively the teachers integrated the 4Cs into their instructions. Classroom observations, totaling eighteen sessions across three different classes for each teacher, were recorded via video for further analysis.

Data and Analysis

Data for analysis were sourced from three key components: lesson plans, teacher interview transcripts, and classroom observations. Utilizing multiple data sources aimed to provide comprehensive insights into how teachers integrate the 4Cs into their chemistry lessons and practices. The analysis, guided by the research questions, involved the separate examination of each dataset to identify key variables pertaining to factors considered by teachers when developing 4Cs-integrated lesson plans, selecting pedagogical strategies, and evaluating their teaching. Subsequently, cross-case patterns were aggregated from all data sources to address the research questions, exploring the integration of the 4Cs into chemistry lesson plans and their implementation in actual classrooms.

The initial focus was on examining teachers' lesson plans, assessing their adherence to components mandated by the Indonesia Secondary Education Process Standards (Ariyana et al., 2018; The Indonesia Directorate General for Vocational Secondary Education, 2018). According to MoEC regulation number 22 of 2016, a lesson plan must encompass basic competencies of science, measurable learning objectives, teaching strategies, teaching media and resources, learning scenarios, and assessment tools focused on developing student character and skills for the 21st century. The EdLeader21 4C rubric, aligned with the Indonesia C13 revision's adoption of the P21 framework, was employed to identify the integration of the 4Cs into chemistry lesson plans.

Following the assessment of lesson plans, audio-recorded interview data were transcribed, and transcripts were subjected to member checking for accuracy. After participants confirmed the accuracy of their interview transcripts, the data were entered into a computer database and analyzed using NVivo 12. Transcriptions were coded and categorized, addressing research questions related to teaching preparation, factors influencing lesson design, instructional strategies for 4C integration, and evaluation of the learning process.

A coding scheme, initially developed and refined, resulted in four overarching categories: teaching preparation, teaching strategy for 4C integration, teaching evaluation, and teacher reflection. These categories were corroborated through an analytical re-analysis of all collected data, providing insights into "how" Indonesia vocational high school chemistry teachers prepared for and implemented the integration of the 4Cs into science instruction (Yin, 2018).

Results

The analysis focused on the teachers' considerations when developing 4C-integrated lesson plans, their selection of pedagogical strategies, the assessment of their teaching, and potential follow-up actions in response to the research questions. Cross-case and within-case analyses are presented.

Cross-Case Analysis

Teaching Preparation

Teachers are tasked with preparing for teaching by creating lesson plans that seamlessly integrate the 4Cs, addressing the National Competency Standard and Basic Competencies. This involves outlining learning goals and indicators, selecting teaching methods to achieve objectives, utilizing supporting resources, structuring learning phases, and evaluating student progress and outcomes in alignment with curriculum guidelines. An analysis of their teaching plans revealed that the teachers effectively adhered to the Indonesian national guidelines (refer to Table 2 below).

Table 2. Lesson plan evaluation score

Teacher	Lesson Plan 1			Lesson Plan 2			Lesson Plan 3		
	Subject	Score	Teaching strategy	Subject	Score	Teaching strategy	Subject	Score	Teaching strategy
Mrs. Dewi	Oxidation-Reduction Reactions: The concept	92.03	Problem-Based Learning	Oxidation-Reduction Reactions: Rules for oxidation number	92.03	Problem-Based Learning			
Mrs. Ratna	Acid-Base Indicator	94.20	Problem-Based Learning	Acid-Base; pH	89.13	Guided discovery learning	Creative and entrepreneurial product: Dish wash mass production	86.70	Problem-Based Learning
Mr. Budi	Formula mass and the mole concept: Molar mass	90.56	Guided discovery learning	Formula mass and the mole concept: molar volume of gas	90.56	Guided discovery learning			

Upon confirming compliance with the national curriculum guidelines, further analysis delved into the factors influencing teachers in the preparation of their lesson plans. During interviews, Mr. Budi emphasized the need for clear instruction that considers the characteristics of students to achieve learning objectives. He articulated:

> I will consider students' characteristics, as each classroom has active and less active students. While, in general, most of them are keen to study, engage in classroom activities, and can think critically, I do find some students who are less involved." (Budi's transcript lines 23-26)

Teachers underscored the significance of providing diverse learning experiences that incorporate visual, auditory, and psychomotor activities. Mrs. Ratna emphasized understanding the unique needs and academic abilities of students:

> Every class is unique. We ought to understand the needs of students and the difference in their academic ability... I use a number of techniques, such as using video and animations. It seems like students are more interested in visual learning." (Ratna's transcript lines 10-11, 96-98)

Mrs. Dewi shared her perspective on tailoring teaching methods to the preferences of students:

> I must take into account the choice of students for presenting their projects. Some students prefer to interact using science presentations, and others enjoy writing a song to memorize chemistry vocabulary." (Dewi's transcript lines 228-232)

Teachers stressed the importance of active student engagement, considering diverse academic abilities, learning habits, and social and cultural backgrounds that impact learning engagement. They highlighted the need for varied instructional approaches to maintain student enthusiasm, as Mrs. Dewi explained:

> Sometimes I use the same approaches for the same chemistry topic, sometimes it could be different. It depends. So that students don't get bored. Varied approaches would make students more excited about studying… The main point is to motivate students to learn (Dewi's transcript lines 130-131, 148).

Additionally, teachers considered the availability of learning support and school facilities, including laboratory equipment, multimedia, and presentation tools. Both Mr. Budi and Ms. Ratna emphasized the importance of considering "the availability of school facilities, learning equipment, and learning media" to support effective teaching. Mrs. Ratna expressed concerns over the lack of learning facilities and tools in chemistry labs, prompting adjustments to instruction:

> Since we have minimal laboratory resources, we use images, video, or animation presentations. Students are asked to watch, observe the video, and then explain what they see (Ratna's transcript line 81-90).

The analysis of teaching preparation identifies key factors influencing teachers' decisions to develop 4C-integrated science instruction, including student characteristics, school support, and the availability of learning facilities and infrastructure.

Teaching Strategies to Integrate 4C

Teachers emphasized the importance of selecting teaching strategies that enhance student involvement and motivation in classroom activities. When questioned about their preferred strategies for integrating 4C, all teachers cited discovery learning, project-based learning, and problem-based learning (PBL) as suitable approaches. However, as revealed in the analysis of lesson plans, guided discovery learning and PBL emerged as the preferred strategies.

Mrs. Ratna explained that the choice between PBL and discovery learning depends on the subject, expressing a preference for discovery learning:

> The integration of 4C depends on the subject. I rarely use PBL; I mostly use discovery learning. I think it's a bit complicated to use PBL, particularly for vocational students… This appears to be more of a student factor. Students are more enthusiastic and focused on vocational subjects than general subjects such as chemistry. (Ratna's transcript lines 212-214, 228-234)

Mr. Budi, when selecting a strategy, considered his familiarity and convenience with the teaching approach:

> I consider my capability in mastering the teaching strategy that I will use for teaching and learning. I will ask myself, 'Am I able to use this approach or any other approach?' When I believe I have mastered the learning model, then I will use it. There are several teaching strategies, but it seems better to use guided discovery learning. I chose this strategy because I mastered this teaching approach (Budi's transcript lines 15-18).

Mr. Budi believed that guided discovery learning allows students to acquire 4C skills through constructive discussions, observation, and active questioning. He emphasized the need for teachers to guide students in the learning process, facilitating a shift in teaching methods to align with the changing nature of student learning:

> The way students learn now is different from the way we used to. We used to be given the chemistry formula, explained the symbols, memorized the formula, and then solved problems. But now, students are expected to study on their own, to search and find data, to interpret and correlate knowledge by

> themselves. The teacher's role is to guide students so that they can gather information and deduce the formula being studied (Budi's transcript lines 132-136).

Teachers also stressed the importance of providing practical knowledge relevant to students' everyday lives. Connecting chemistry concepts with daily experiences was seen as a method to arouse curiosity and engagement. Mrs. Dewi mentioned using probing questions in the introduction to motivate students and relate chemistry to real-life situations:

> In the introduction, I use probing questions about the importance of the topic we discussed that day in everyday life to build a student's motivation to learn it. We need to relate chemistry to real life so that students can find it easier to understand and apply the principles further in everyday life (Dewi's transcript lines 38-40).

Mrs. Ratna shared her approach of linking chemistry concepts to students' daily lives, promoting curiosity and understanding:

> When students study acid-based or oxidation-reduction reactions, I give examples from daily lives... I see students respond more when discussing it, and I think it makes them realize that chemistry concepts exist and are close to them (Ratna's transcript lines 107-109, 114-115).

Furthermore, Mrs. Ratna described an activity where students produced marketable products, fostering creativity, innovation, teamwork, and effective communication:

> Students are asked to produce marketable products, such as dishwasher soap, floor cleaner, and hand sanitizer. This allows students to be creative, innovative, work in a team, and communicate effectively. Each group needs to calculate the production cost, determine the sale price, and create their own label for the product (Ratna's transcript lines 202-210).

This teaching approach was perceived to develop not only 4C skills but also entrepreneurial skills in students. Teachers also emphasized the importance of facilitating learning environments that encourage students to ask questions, build confidence, and stimulate curiosity. Mr. Budi highlighted his preference for learning models involving observations, encouraging students to actively ask questions. Mrs. Ratna and Mrs. Dewi emphasized the value of videos, simulations, and building trust among students to enhance engagement and interaction. The following sections provide a summary of teachers' explanations on fostering the integration of each 4C.

Communication Skills: All three participants said that it is important for students to have good communication skills. Mrs. Dewi said that to help students develop their communication skill,

> ...in the beginning of the lesson, I encourage students to communicate their thoughts by asking them questions related to topic will be discussed (Dewi's transcript lines 72-73).

She emphasized promoting multiple ways of communication during instruction including student-to-teacher, teacher-to-student and student-to-student interactions. She also encourages students to share their thoughts and opinions without being fear of making mistakes because they are part of the learning process. In addition, Mr. Budi expressed that through group discussions and classroom presentation,

> Students will learn to communicate with others, so that they can speak clearly, listen more, and feel more comfortable in communicating to others (Budi's transcript lines 139-141).

Collaboration Skills: Teachers in this study shared their strategies to encourage student engagement through group work and peer learning for student collaboration. The student working groups could be either small or large depending on the subject. Mrs. Dewi stressed her preference for grouping students so as to diversify gender and academic abilities within each group. In this way, she added:

> …students can communicate with each other not only with same gender, but with another, so that they can learn to equally interact, to share their views and to respect the views of others (Dewi's transcript lines 95-97).

Mrs. Ratna suggested checking student's participation regularly and sharing tasks among group members for effective work in a group.

Critical Thinking and Problem Solving: Teachers in this study generally favored techniques involving students in the study of observable natural phenomena or events, emphasizing critical thinking and problem-solving skills. Mr. Budi provided an example:

> In studying mass molar, initially, students were asked to look at the images on the screens, observe them, so from that insight, students are asked what they see, what questions emerge as they look at those pictures. Then, I continued using probing questions to guide students to find out the mass molar formula (Budi's transcript lines 139-141).

Mrs. Dewi illustrated a strategy for critical thinking and problem-solving in the context of teaching oxidation-reduction reactions. She explained:

> First, for literacy tasks, in the previous meeting, students were given homework to read about oxidation and reduction reactions and make notes. Students can use any resources, including online sources. In the next meeting, during the introduction session, we discuss what students learned from their reading homework and related the application of redox reaction in their daily lives to arouse their interest… Students have to think critically because they were expected to search and discover themselves, to analyze, and be able to connect it to the concepts they have learned previously (Dewi's transcript lines 41-67).

Creativity and Innovation: In the interviews, teachers expressed their dedication to integrating 4C in their teaching, particularly activities fostering creativity and innovation skills in chemistry instructions. However, they acknowledged the challenges, with Mr. Budi stating:

> In my view, it is difficult to apply creative and innovative thinking to all chemistry learning. The 4C integrated instruction must therefore be tailored to the content and the abilities of students (Budi's transcript lines 162-165).

Mrs. Ratna highlighted the demands of encouraging innovative thinking and creating something new, acknowledging the difficulty. She commented:

> Innovative thinking means encouraging students to create something new. It seems like… it is demanding for students to create something new. In my opinion, it's rather difficult. But, for other skills, such as critical thinking and problem-solving, communication, and collaboration skills, students can practice them, and these skills can be integrated into most chemistry lessons (Ratna's transcript lines 200-204).

Table 3. Lesson plan: 4C integration

Teacher	Lesson Plan 1		Lesson Plan 2		Lesson Plan 3	
	Subject	4C integration	Subject	4C integration	Subject	4C integration
Mrs. Dewi	Oxidation-Reduction Reactions: The concept	Communication Critical thinking Collaboration.	Oxidation-Reduction Reactions: Rules for oxidation number	Communication Critical thinking Collaboration		
Mrs. Ratna	Acid-Base Indicator	Communication, Collaboration, Critical thinking	Acid-Base pH	Communication, Collaboration, Critical thinking	Creative and entrepreneurial product: Dish wash mass production	Communication, Collaboration, Critical thinking Creativity and innovation
Mr. Budi	Formula mass and the mole concept: Molar mass	Communication Critical thinking collaboration	Formula mass and the mole concept: molar volume of gas	Communication Critical thinking collaboration		

Most of what the three teachers conveyed about integrating the 4C skills was also reflected in their lesson plans, as shown in Table 3. The skills of communication, collaboration, critical thinking and problem solving, literacy, self-confidence, and curiosity were most commonly listed in the lesson plans. However, only Mr. Budi and Mrs. Dewi consistently articulated the development of 4C as part of their teaching objectives at the beginning of the instruction. The analysis of the extent to which teachers promote the integration of 4C skills in chemistry is shown in Table 4.

Table 4. The 4Cs integration

4C Skills	Mrs. Dewi		Mrs. Ratna		Mr. Budi		
	Oxidation-Reduction Reactions: The concept	Oxidation-Reduction Reactions: Rules for oxidation number	Acid-Base Solution	Acid-Base; pH	Creative and entrepreneurial product: Dish wash mass production	Formula mass and the mole concept: Molar mass	Formula mass and the mole concept: molar volume of gas
Creativity and Innovation							
• Think creatively	NA	NA	NA	NA	Approaching standard	NA	NA
• Work creatively with other	NA	NA	NA	NA	Meet the standard	NA	NA
• Implement innovation	NA	NA	NA	NA	Meet the standard	NA	NA
Critical thinking and problem solving							
• Reason effectively	Meet the standard	Approaching standard	Approaching standard	Approaching standard	Meet the standard	Approaching standard	Approaching standard
• Use system thinking	Meet the standard	Approaching standard	Approaching standard	Approaching standard	Meet the standard	Meet the standard	Meet the standard
• Make judgment and decision	Meet the standard	Approaching standard	Approaching standard	Approaching standard	Approaching standard	Approaching standard	Approaching standard
• Solve problem	Approaching standard	Approaching standard	Approaching standard	Approaching standard	Meet the standard	Approaching standard	Approaching standard
Communication							
• Communicate clearly	Meet the standard	Approaching standard	Approaching standard	Approaching standard	Approaching standard	Meet the standard	Meet the standard
Collaboration							
• Collaborate with others	Meet the standard	Meet the standard	Approaching standard	Approaching standard	Meet the standard	Approaching standard	Approaching standard

Teaching Evaluation

Teachers said that learning goals need to be identified and that those learning objectives must be communicated at the beginning of the class. Stating the learning objectives, teachers added, would let students know what they are going to learn, help guide learning processes, and then, by the end of the learning process, both teachers and students could wrap up what they have learned and allow the teacher to assess whether the learning is consistent with the initial objectives. Teachers suggest that they assess their teaching by reviewing student response to the teaching strategies and the results of student assessment.

Mr. Budi expressed his view that effective instruction can be seen as improving student participation and engagement in class activities regularly, asking questions and engaging in discussions, focusing on learning topics and successfully solving problems. Students will also focus on the issues quickly to find a solution. Additionally, Mrs. Dewi articulated that:

> … and after class, students still come to me to ask questions, to discuss topics that have already been discussed… Even when students are in the upper classes, they could recall what they learned. That is in my opinion, students liked what we were learning in class using these methods. (Dewi's transcript lines 163-174)

Mrs. Dewi added that if students are able to express their thoughts confidently, communicate and listen to their peers better, be able to respond to dissension and speak scientifically, this indicates that students have acquired communication and collaboration skills (Dewi's transcript lines 286-290). In addition, Ms. Ratna discussed that the ability of students to apply their knowledge to practical problems, their persistence in trying formulas for their entrepreneurial project, indicate a thorough thinking and the creativity of students.

However, teachers addressed their teaching evaluation differently. Mr. Budi, for example, stated that he used guided discovery and group discussion to foster communication, collaboration and critical thinking skills. After teaching these approaches in his first of the three classrooms he taught, he realized that using group discussion often takes more time for students to discover the formula on their own. Mr. Budi said he would use the same teaching strategy, but better manage the time for the next class on the same subject during the learning process. Mr. Budi also said that he would call on students to encourage them to ask questions, to communicate their opinions, to answer questions, and to respond to the ideas of other students.

Teachers also reported on the use of student assessments to evaluate their teaching while also evaluating student learning. As per Mrs. Dewi, she always carried out an assessment after each learning session. The assessment may be done individually or in a group. She said that if most students had good results above the minimum standard of completeness, she considered the instruction to have been successful. She added that she would review at the next meeting by asking what the students had learned at the previous meeting. She suggested that if students are able to define the concepts of chemistry in their own words, it could be an insight into their understanding. Mrs. Dewi also suggested that different students have different responses toward a certain teaching strategy. Once, she found that in one of the classes she taught, students were less enthusiastic about the strategy she used. After that, she would change the strategy. Likewise, Mrs. Ratna used student assessment to evaluate her teaching. She shared:

> … If it turned out that the student's grade did not meet the requirement of completeness standard. So, it can be concluded that the students did not grasp the learning, many of them did not understand the subject they learned that day. (Ratna's transcript lines 136-138).

Similarly, Mrs. Ratna also intended to change the teaching strategy. Mrs. Ratna also said that sometimes, instead of using an initial plan for students to find out the concept being studied, she would turn the instruction back into a regular lecture, which she thought would be more effective in explaining the concept of science. Then, she used the students' group discussion to practice solving the problems of the concept being studied. Not only Mrs. Ratna, who considered using lectures, Mr. Budi said that he would prefer to use lectures if he did not master and had less confidence in a certain teaching approach.

Teacher Reflection

All teachers shared a unanimous perspective on the value of 4C-integrated chemistry learning in facilitating the development of 21st-century skills. They emphasized that integrating 4C into science instruction promotes students' active involvement in learning. The teachers collectively agreed on the importance of preparing students to communicate effectively, build self-confidence, develop mutual behaviors, think critically, stay motivated, and increase their interest in understanding and applying chemical concepts in everyday life. They acknowledged their efforts to align with the curriculum revision for integrating 4C into chemistry learning. However, they also acknowledged that not all lessons went well in every classroom, highlighting the challenges of consistent implementation.

Furthermore, the teachers recognized the difficulty of fully integrating the skills of creativity and innovation. Despite their efforts, the analysis of 4C integration into chemistry learning indicated variations ranging from "approaching standard" to "meeting standard" in both lesson plans and classroom practices. Table 4 provides a detailed analysis of the extent to which teachers successfully integrated 4C skills in their chemistry lessons.

Cross-Case Synthesis

The evaluation of the lesson plan rubric scores indicates that, in general, teachers adhered to the curriculum guidelines when developing their chemistry lesson plans. Despite this adherence, teachers provided diverse descriptions of how they integrated the 4Cs into their plans. Addressing the first research question concerning factors considered when developing a science lesson plan focusing on 4C integration, the analysis revealed that teachers take into account student characteristics, the availability of learning tools, and school facilities. They aim to address diverse intellectual abilities, learning preferences, and social-cultural backgrounds, keeping students engaged while striving to develop 4C skills.

Answering the second research question on explanations for selecting specific teaching strategies to integrate the 4Cs into science learning, the analysis identified factors such as student choices, subject matter, and teacher

mastery of suggested learning strategies influencing the selection of approaches. Teachers unanimously emphasized the value of 4C-integrated chemistry lessons in helping students acquire 21st-century skills. While they reported efforts to integrate 4C into lessons aligned with the 2017 curriculum revision, challenges were noted in fully integrating creativity and innovation skills. Classroom observations revealed common strategies like interactive lectures, probing questions, and group discussions.

The third research question explored how teachers assess and judge the appropriateness of their science lesson plans. The analysis of interviews and lesson plan evaluations suggested alignment with curriculum guidelines. Teachers incorporated classroom discussions, peer learning, and probing questions to build students' confidence, foster collaboration, and stimulate critical thinking. Assessment considered students' positive responses, engagement, and learning outcomes. Mrs. Dewi highlighted indicators like students confidently articulating thoughts, engaging in scientific discourse, and effectively participating in group work. While all teachers weighed positive student responses and participation, there were variations in approaches to teaching evaluation. For instance, Mr. Budi preferred maintaining the same strategy with improved time management, while Mrs. Dewi and Mrs. Ratna opted for changing teaching strategies. Additionally, both Mrs. Ratna and Mr. Budi expressed a preference for lectures as an alternative teaching approach.

Within-Case Synthesis

Mrs. Dewi, a seasoned teacher with 20 years of experience, attended Teacher Professional Training and Education (TPTE) in 2007, predating the 2017 curriculum revision. Despite this, she expressed a willingness to learn about the revision and 4C integration through literature and team teaching. Interviews and classroom observations revealed her confidence and effective classroom management derived from her extensive teaching experience. Mrs. Dewi demonstrated concerted efforts to incorporate the 4Cs into her teachings, verbally articulating them in her learning objectives.

A mid-career teacher with ten years of experience, Mrs. Ratna attended Teacher Professional Education (TPE) in 2018. Despite her participation in professional development and belief in the benefits of 4C integration, she expressed reservations about students meeting learning expectations. This skepticism was reflected in her teaching approach, with lectures dominating the knowledge transfer in her classrooms as she navigated the challenges of integrating the 4Cs.

Another mid-career teacher with ten years of experience, Mr. Budi attended Teacher Professional Education (TPE) in 2019. Sharing insights from TPTE, he emphasized the significance of guided discovery learning, the 2017 curriculum revision, and 4C integration in chemistry lessons. Mr. Budi consistently integrated the 4Cs into his plans, interviews, and classroom articulations, even incorporating a rubric for skills assessment in lesson plans. Having access to various resources and an intensive professional development program, especially in 4C integration, contributed to his confidence in implementing these strategies.

Discussion

The exploration of pedagogical strategies and the integration of 4C into chemistry learning among vocational high school chemistry teachers in Indonesia revealed multifaceted influences on teachers' decisions, encompassing student factors, learning tools and facilities, and individual teacher considerations. Teachers emphasized the importance of addressing students' characteristics and diversities, leveraging available learning facilities, and mastering specific pedagogical approaches for successful 4C integration. While all teachers aimed for active learning, teamwork, effective communication, and problem-solving, not all explicitly highlighted 4C integration in their learning objectives. Research suggests that explicit teaching of 21st-century skills is crucial, and a lack of explicit focus may hinder skill development (Saavedra & Opfer, 2012; Schleicher, 2012).

Despite variations, all teachers expressed positive views on integrating the 4Cs into chemistry learning, aligning with the mandates of the curriculum revision. The importance attached to 4C integration by teachers should drive transformative changes in classroom practices (Shear et al., 2010). Teachers demonstrated an understanding of effective teaching fundamentals and proposed strategies, such as guided discovery learning and PBL, to foster 4C development. However, the integration of 4Cs was found to be at a basic level, ranging from approaching standard to meeting the standard. This echoes findings from previous studies, indicating that while teachers acknowledge the importance of 21st-century skills, they may feel less prepared to integrate them (Clarke, 2014; Thijs et al., 2014).

Challenges were particularly noted in fostering creativity and innovation, reflecting existing literature emphasizing the role of teachers in promoting creativity (Cropley, 1995; Park et al., 2006). Continuous support and efforts to enhance teachers' confidence in nurturing creativity and innovation skills are deemed essential. Despite guidelines from the Ministry of Education and Culture (MoEC), practical and contextual experiences are necessary for effective implementation, emphasizing the need for ongoing support and training.

Efforts to incorporate technology and encourage online learning sources were seen positively, aligning with student preferences for internet media. However, there's a need to guide students in discerning trustworthy sources. While teachers expressed efforts to utilize technology, caution is required to avoid a technology-based transmission model, ensuring technology serves to enhance student-centered activities. Challenges persist in fully adopting inquiry-based strategies, suggesting the need for further teacher training and support.

Conclusion

This study delved into the integration of 4C (Communication, Collaboration, Critical Thinking, and Creativity) skills in chemistry teaching among vocational high school teachers in Indonesia. The findings, based on teachers' self-reports, lesson plans, and classroom observations, illuminate several key aspects:

Varied Implementation Across Schools: Among the participating public and private vocational high schools in the region, only science teachers from two public schools reported moderate to high levels of 4C integration. This contrasts with the national goal of developing Higher Order Thinking Skills (HOTS) and 4C among students, indicating that the implementation of the C13 revision has been limited across schools.

Influential Factors: Teachers' integration of 4C skills is influenced by student characteristics, learning tools, school facilities, and teacher mastery of pedagogies. While efforts have been made to integrate communication, collaboration, and critical thinking, challenges persist in incorporating creativity and innovation skills.

Dominance of Interactive Lectures: Despite attempts at integrating 4Cs, observations reveal that interactive lectures remain the predominant teaching approach used by teachers.

The study underscores the challenges in achieving the Indonesian national goal of integrating 4Cs into education to meet 21st-century needs. The current curriculum guidelines lack detailed descriptions and guidance on the implementation and assessment of 4C integration. There is a clear need for improved curriculum and instructional guidelines that provide comprehensive support to teachers. Professional development opportunities should prioritize the practical implementation of 4Cs, with a specific focus on fostering creativity and innovation skills.

The discussion highlights the nuanced landscape of 4C integration in chemistry learning, with both positive strides and challenges. Ongoing professional development, explicit teaching of 21st-century skills, and a balance in technology use are crucial elements in advancing effective pedagogical strategies and realizing the full potential of 4C integration in the Indonesian vocational high school context.
The Indonesian experience offers insights applicable to other countries with similar aspirations for 21st-century education. While cultural and linguistic differences exist, the common interest in enhancing workforce education aligns with global initiatives like the Partnership for 21st Century Skills. Therefore, countries aiming for effective 4C integration can benefit from providing teachers with robust professional development, along with accessible resources such as curriculum guides and online materials specifically addressing the details of integration, instruction, and assessment of 4C learning. This approach can contribute to a more successful realization of educational goals in the rapidly evolving landscape of the 21st century.

Scientific Ethics Declaration

References

Afandi, Sajidan, Akhyar, M., & Suryani, N. (2019). Development frameworks of the Indonesian partnership 21 st -century skills standards for prospective science teachers: A Delphi study. *Jurnal Pendidikan IPA Indonesia*, *8*(1), 89–100. https://doi.org/10.15294/jpii.v8i1.11647

Ariyana, Y., Pudjiastuti, A., Bestary, R., & Zamromi, Z. (2018). *Buku pegangan keterampilan berpikir tingkat tinggi berbasis zonasi*. *Direktorat Jendral Guru dan Tenaga Kependidikan*. Direktorat Jendral Guru dan Tenaga Kependidikan.

Boix Mansilla, V., & Bughin, J. (2011). Preparing our youth to engage the world. *Educating for Global Competence*, 1–136. Retrieved from papers2://publication/uuid/CB6743CB-9C89-4AAF-831E-5124907F4569

Bybee, R. W., & Fuchs, B. (2006). Preparing the 21st century workforce : A new reform in science and technology education. *Journal of Research in Science Teaching*, *43*(4), 349–352. https://doi.org/10.1002/tea

Clarke, J. T. (2014). *Twenty first century teaching and learning: What do teachers know and what motivates them to change?* The College of Saint Elizabeth. Retrieved from ProQuest Dissertations & Theses Global UMI UMI 3619930

Cresswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: SAGE.

Cresswell, J. W., & Miler, D. L. (2000). Determining validity in qualitative inquiry, Theory into Practice,. *Theory into Practice*, *39*(25 Jun 2010), 124–130. https://doi.org/10.1207/s15430421tip3903

Cropley, A. J. (1995). *Fostering creativity in the classroom : General principles. In M. Runco (Ed.), The creativity research handbook Vol. 1 (pp.83-114).* (Vol. 1). Cresskill, NJ: Hampton Press.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Dede, C. (2005). Planning for neomillennial learning styles. *World Wide Web Internet And Web Information Systems*, *28*(1), 7–12. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download? https://doi.org/10.1.1.119.9896&rep=rep1&type=pdf

EdLeader21. (n.d.). *21st Century skills standards rubric*. Retrieved from https://www.k12.wa.us/file/36249

Erimurti, K. (n.d.). *Pendidikan abad 21 dan implementasinya pada pembelajaran di Sekolah Menengah Kejuruan (SMK) untuk paket keahlian desain interior*. *Artikel Kurikulum 2013 SMK*.

Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study. *Academy of Business, Engineering and Science Halmstad University, Sweden*, 1–15. Retrieved from http://www.diva-portal.org/smash/record.jsf?pid=diva2:1064378%0Ahttp://www.diva-portal.org/smash/get/diva2:1064378/FULLTEXT01.pdf

Haryani, E., Cobern, W. W., & Pleasants, B. A.-S. (2019). Indonesia Vocational High School science teachers' priorities regarding 21st century learning skills in their science classrooms. *Journal of Research in Science Mathematics and Technology Education*, *2*(2), 105–133. https://doi.org/10.31756/jrsmte.224

Immordino-Yang, M. H., & Damasio, A. (2011). We feel, therefore we learn: The relevance of affective and social neuroscience to education. *LEARNing Landscapes*, *5*(1), 115–131. https://doi.org/10.36510/learnland.v5i1.535

Mertens. M., D. (n.d.). *Research and evaluation in education and psychology. Integrating diversity with quantitative, qualitative, and mixed methods*. Thousand Oaks, California: SAGE. https://books.google.com/books?id=DVs-I4dn2CUC&printsec=frontcover&dq=Research+and+Evaluation+in+Education+and+Psychology&ei=q3cTX56aGKCGjMcPgIux4AQ&cd=1

Oliver, B. (2016). *Strategies that promote 21 st century skills what steps can we take to incorporate*. Retrieved from https://justaskpublications.com/just-ask-resource-center/e-newsletters/just-for-the-asking/strategies-that-promote-21st-century-skills/

Park, S., Lee, S. Y., Oliver, J. S., & Cramond, B. (2006). Changes in Korean science teachers' perceptions of creativity and science teaching after participating in an overseas professional development program. *Journal of Science Teacher Education*, *17*(1), 37–64. https://doi.org/10.1007/s10972-006-9009-4

Partnership For 21st Century Skills (P21). (2009). *21st framework definitions*. Retrieved from http://www.p21.org/documents/P21_Framework_Definitions.pdf

Priyatni, E. T., & As'ari, A. R. (2019). Project-based learning paper: Learning model to develop 4Cs (critical and creative thinking, collaboration and communication skills). *Advances in Social Science, Education and Humanities Research*, *335*(ICESSHum), 441–448. https://doi.org/10.2991/icesshum-19.2019.72

Ramdiah, S., Abidinsyah, Royani, M., & Husamah. (2019). Understanding, planning, and implementation of HOTS by senior high school biology teachers in Banjarmasin-Indonesia. *International Journal of*

Instruction, *12*(1), 425–440. https://doi.org/10.29333/iji.2019.12128a

Saavedra, A. R., & Opfer, V. D. (2012). *Teaching and learning 21st century skills: Lessons from the learning sciences* (pp. 1–35). Paper presented at the joint AARE/ APERA Conference, Sidney, Australia. https://www.aare.edu.au/data/publications/2012/Saavedra12.pdf

Schleicher, A. (2012). *Preparing teachers and developing school leaders for the 21st century*. OECD Publishing. https://doi.org/10.1787/9789264174559-en

Senechal, D. (2010). The most daring education reform of all. *American Educator*, *Spring*, 4–16.

Shear, L., Novais, G., Means, B., Gallagher, L., & Langworthy, M. (2010). ITL research design document, (November). http://www.itlresearch.com/index.php?option=com_content&view=article&id=15:research-design&catid=10&Itemid=5

The Indonesia Directorate General for Vocational Secondary Education. (2018). *Pelatihan dan pendampingan implementasi kurikulum 2013 Sekolah Menengah Kejuruan*. *Kementrian Pendidikan dan Kebudayaan.*

The National Education Association, N. (2012). *Preparing 21st century students for a global society: An educator's guide to "the four Cs."* Washington, DC: Author.

Thijs, A., Fisser, P., & Hoeven, M. van der. (2014). *21e eeuwse vaardigheden in het curriculum van het funderend onderwijs[21st century skills in the curriculum of basic education]*.

Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times*. San Fransisco, California: Jossey-Bass A wiley Imprint. Retrieved from www.josseybass.com

Uminingtyas, M. P. K., Sukarmin, S., & Suryana, R. (2019). The profile of 21st century learning: Enhancing critical thinking and problem solving skills at Senior High School. *Advances in Social Science, Education and Humanities Research*, *253*(Aes 2018), 24–30. https://doi.org/10.2991/aes-18.2019.7

Winaryati, E. (2018). Penilaian kompetensi siswa abad 21. In *Prosiding Seminar Nasional & Internasional* (Vol. 1, pp. 6–19).

Yin. K., R. (2018). *Case study research and applications design and methods* (sixth edit). Thousand Oaks, California: SAGE.

Author(s) Information

Esty Haryani
Department of Education and Culture
West Kalimantan Province, Indonesia 78116
Indonesia
Contact e-mail: esty.haryani@gmail.com
ORCID iD: https://orcid.org/0000-0002-1843-4873

William W. Cobern
The Mallinson Institute, Western Michigan University
Kalamazoo, MI 49008, U.S.A.
ORCID iD: https://orcid.org/0000-0002-0219-203X

Brandy Ann-Skjold Pleasants
The Mallinson Institute, Western Michigan University
Kalamazoo, MI 49008 , U.S.A.
ORCID : https://orcid.org/0000-0001-7678-492X

Marcia K. Fetters
The Mallinson Institute, Western Michigan University
Kalamazoo, MI 49008, U.S.A.
ORCID: https://orcid.org/0009-0002-1962-6356