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UNPACKING THE 4CS: THE QUALITATIVE CONTENT ANALYSIS OF 21ST CENTURY LEARNING SKILLS IN PHYSICS TEXTBOOK (GRADE IX)

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ABSTRACT

This study examines representation of 21st century learning skills, namely 4Cs: critical thinking, communication, collaboration, and creativity, within physics book for Grade IX published by Punjab Curriculum and Textbook Board. This study employed qualitative content analysis using purposive sampling to select the book. It examined how these essential competencies cut across textbook and assessed both facilitative and restrictive teaching and learning strategies. The study demonstrates that 4Cs are neither fully realized nor equally emphasized, with critical thinking focused on problem -solving assignments, conceptual questions, and creativity being the least stressed. The textbook prioritizes the traditional, content-driven instruction over integrated development of 21st century competencies. These findings highlight the need for curriculum designers and textbook writers to more consciously incorporate 4Cs into instructional materials, enabling students to not only acquire scientific knowledge but also develop essential skills for modern scientific inquiry and interdisciplinary collaboration. In this regard, more balanced and intentional integration of the 4Cs is needed to align physics education with contemporary educational and professional demands.

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INTRODUCTION

As the world becomes increasingly technological, diverse, competitive, and challenging, education systems worldwide are shifting from ideas of imparting knowledge for their own sake alone, with particular attention to skills that shall be useful in future (Voogt & Roblin, 2012). Of these skills, 4C's, critical thinking, communication, collaboration, and creativity, have been established as vital skills, irrespective of the model being followed in educational frameworks, such as Partnership for 21st Century Skills, 2009 (Griffin, McGaw & Care, 2012). Physics can be regarded as a subject with guidelines for problem-solving approaches. Thus, it can be concluded that this is one of appropriate subjects for developing these skills in students. Textbooks are considered key sources of information in classrooms today, especially in developing states, where more copies of supplementary materials may be out of reach (Valverde, 2002). The textbooks contain both content knowledge and teaching approaches; thus, they impact classroom practices and learning/teaching schemes (Chiappetta & Fillman, 2007). About design and content, the educational technologies express education priorities and influence students' interactions with material, making them key promoters of acquisition of 21st century competencies.

Textbook analysis has been done regarding different subjects like in Pakistan Studies (Muhammad & Brett, 2015), English (Jamil, Anwar, & Sohail, 2024). Similar to education systems of countries across the world, Pakistan has come to understand the need to recognize its current curriculum. In line with the elements of National Curriculum for Physics (2006, revised in 2023), scientific literacy and inquiry skills are seen as important alongside subject content. Still, these curricular intentions are significant, yet difficulties arise when translating them into learning diverse products (Kandiko, Howson & Kingsbury, 2023). This study intends to fill this gap by exploring a qualitative content analysis of a Grade IX Physics textbook developed and published by the Punjab Curriculum and Textbook Board, revised according to the National Curriculum of Pakistan-2023, with particular emphasis on how 4Cs are presented and used in the text and not an accessory to, content knowledge in science education. In this linking, the critical thinking in any subject, particularly physics, is the ability to reason systematically regarding the analysis of evidence, assertions, pattern recognition, and logical reasoning (Furqon, Sinaga & Riza, 2023). Because most physical concepts are abstract, thus, thinker must be able to move back and forth quite actively between the theoretical models as well as phenomena.

Critical thinking can be improved when teaching and learning physics is anchored on enhancing skills, as opposed to it being a by-product of teaching content and knowledge (Shadowens, 2023). The communication is another skill that incorporates scientific concepts using the formal academic language and representation. The development of communication skills is necessary to construct the explanations, engage in scientific arguments, and participate in knowledge building. Textbooks also focus on transmission of factual knowledge rather than on the development of communication practices (Golubeva, Wagner & Yakimowski, 2017). Another skill is collaboration, which is critical for the problem-solving and scientific advancement in complex domains (Shouse, Schweingruber & Duschl, 2007). Collaborative learning is associated with an improved conceptual understanding of physics with problem-solving strategies. In this linking, collaborative cognition involves creating meaning, division of work, and constructing new knowledge, elements that need to be specifically facilitated through instruction. In science education, the creativity refers to the ability to generate novel ideas, design investigations, possess new ideas, present new facts related towards a problem, formulate hypotheses along with mechanisms and suggest new solutions (Hadzigeorgiou, Fokialis & Kabouropoulou, 2012).

In physics, creativity involves formation of hypotheses, experimentation & theoretical construction. There is often a feeling due to presentation of physics, which is described as a collection of known facts rather than creation of imagination. Einstein states, knowledge is just imagination. According to Khalick, Myers, Summers, Waight, Zeineddin and Belarmino (2017), there are minimal chances to engage students in creative aspects of logical practice. Patston, Kaufman, Cropley and Marrone (2021), creativity is universally recognized as valuable in policies and curricula that offer minimum specific support assessment criteria, mechanisms, or pedagogical strategies to significantly translate creative objectives into everyday teaching practice. This study used qualitative content analysis to analyze how and in what ways the 4Cs are reflected in a Pakistani Physics textbook for Grade IX. The findings of this research will contribute to the understanding of what instructional material is already potentially available to provide ideas on the instructional materials that might be better developed for the effective development of 21st century skills. As educational systems worldwide continue to focus these competencies, understanding their current representation in instructional materials is important step toward more effective implementation of 21st century skill development in physics education.

Research Objective

1. To analyze how critical thinking, communication, collaboration, and creativity (the 4Cs) are represented in the Grade IX physics textbook.

LITERATURE REVIEW

There have been increasing concerns about integrating 21st century skills in science learning and education since global education systems are in the process of transitioning to respond to emerging societal and workforce needs. Research on 21st century skills has stressed their standing alongside content knowledge acquisition in preparing students to navigate complex real-world challenges. Chalkiadaki (2018) evaluated diverse frameworks for 21st century skills and identified extensive agreement on the 4Cs as the key competencies. More specifically, these skills have been confirmed and described as important part of, and not an accessory to, content knowledge in science education (Levrini, Fantini, Tasquier, Pecori & Levin, 2015). The studies on expanding connection readiness insistence propose that insight into information other than content matter knowledge is a requisite for students in twenty-first century. To increase the importance of the classroom learning process in science classes, the following are some of the challenges in the implementation of 21st century skills in science classrooms. According to Voogt and Roblin (2012), gaps exist between classroom realities and policy intentions.

Similarly, Bybee (2010) noted that these skills should be taught in the context of science content, while avoiding the conception that they will be learned implicitly from conventional teaching and learning approaches. Another finding suggests that science teachers lack readiness to implement these skills in their teaching and largely rely on available teaching resources (Hilton & Pellegrino, 2012). These implications are important for curriculum developers, textbook authors, and physics teachers who want to apply educational reform objectives to their standards. Text continues to serve as the main educational resource in the classrooms and significantly influences learning. Numerous techniques have been developed to analyze textbook content, with content analysis being the most widely used. The development of students' science capital did not enable them to connect scientific content with their personal and social environments. Also, Chiappetta and Fillman (2007) found that science textbooks inadequately represent the scientific process in the study of four dimensions of scientific literacy.

4Cs in Science Instructional Materials

Communication

Speaking and writing also form a part of the communication process in science education, as it is the ability to read and understand different texts and documents. According to Krajcik and Sutherland (2010), effective ways of supporting communication of scientific understanding in an instructional context include the use of prompts to support the use of scientific vocabulary by means construct of explanations. In this connection, Tang (2020) pointed out that there are high linguistic challenges in science texts and insufficient efforts to build up requisite literacy skills in diverse circumstances. There should be the combined use of pictures and words to build multiple communication skills in science for students.

Collaboration

The review and experience of students, teachers, and experts on collaborative work in learning and teaching have proven that it enhances learning ability, conceptual understanding, and problem-solving techniques better than any other approach. As per Huang (2022), learning by working in a group of students or teamwork was better than tackling problems individually, especially where these problems are complex. Cooperation is naturally possible; it needs a framework within which it will occur. The delineated procedures are as follows. Similarly, Heinimäki, Volet, Jones, Laakkonen and Vauras (2021) observed that analyzing groups in science textbooks, meaningful collaboration is not frequent and most of the activities were completed procedurally instead of building together required knowledge.

Critical Thinking

Extensive research on critical thinking has been conducted in the context of science education. Tiruneh, Cock and Elen (2018) synthesized the critical thinking instruction and revealed it as the best practice within the context of the subject matter. Miri, David and Uri (2007) have listed quite a few effective teaching practices for critical thinking in science: an open and unstructured inquiry approach and use of real-life contexts. Thus, critical thinking has been explored through textbook analysis of the different textbooks (Naseer, Muhammad & Jamil, 2022; Yani, Iranie, R., Jonuarti & Rahim, 2021)

Creativity

The creativity in science education is still considered the least explored among the four Cs. Thus, Hadzigeorgiou et al. (2012) categorized science education as creative in addition to rationality. The Newton and Newton pointed out that the study defined science teachers' conception of creativity in science in a limited way, whereby it was seen as the hands-on activity rather than a conceptual one. Khalick et al. (2017) discussed the findings for students from the textbooks, alerting students to poor opportunities to engage in the creative aspects of science practice, including hypothesis and experiment planning.

Gaps in Literature

The development of 21st century skills in science education has gained significant attention due to evolving demands of modern workforce and society. While numerous studies have demonstrated development of 21st century skills in science education (Asrizal et al., 2022; Gürsoy, 2021; Suastra et al., 2019; Zorlu & Zorlu, 2021), studies have examined the portrayal of such skills in the physics textbooks (Bakri et al., 2023; Bakri & Sunardi, 2022; Oktafianto et al., 2019; Suastra et al., 2019). In the Pakistani context, studies have been conducted on physics in textbook analysis (Jamil, Ain, & Chohan, 2024; Jamil, Bokhari, & Ahmad, 2024; Neswary & Prahani, 2022; Raza et al., 2020) and the curriculum analysis (Akram et al., 2024; Jamil, Hafeez, & Muhammad, 2024). The findings of previous studies pertaining to a general discussion of science textbook characteristics differ, but there has been limited detailed investigation of the application of 4Cs. Thus, the literature review implies that more research is needed to analyze the approach used in textbooks and the framework for 21st century learning. This research seeks to fill these gaps by identifying how Grade IX Physics textbook used in Pakistan may support the development of 4Cs by examining the text through lens of the framework.

RESEARCH METHODOLOGY

The current study was based on qualitative content analysis (Kyngäs, 2020). The physics textbook for grade IX was selected using a purposive sampling technique. Qualitative content analysis with facilitation of NVivo 14 was used to assess the representation of critical thinking, communication, collaboration, and creativity (4Cs) within the Punjab Curriculum as well as Textbook Board (PCTB) published Grade IX Physics textbook. This method stands out for its ability to analyze educational materials systematically so that researchers can detect defined patterns and interpretations within the text (Jackson & Bazeley, 2019). This method has previously been used to analyze textbooks and their various sections, in addition to science content, inquiry processes together with developmental components.

FINDINGS OF STUDY

The data analysis generated the following themes and sub-themes based on the aim of the study. Thus, the representation of the 4Cs, critical thinking, communication, collaboration, and creativity in the textbook

Critical Thinking

The Physics textbook demonstrates the stronger emphasis on critical thinking than the other Cs. It incorporates various elements that encourage analytical thinking, the evaluation of ideas, and the application of concepts to solve the problems. Throughout the text, students are prompted to think logically about the physics principles, analyze the relationships between variables, and apply their conceptual understanding to various contexts. The following are some examples that support these findings. In quick quiz of Chapter 6 (mechanical properties of matter), it is narrated as in following image: (p. 137).

Quick Quiz
Would you exert more, same or less pressure on the ground if you stand on one foot instead of two feet?

In the constructed response questions section of Chapter 3.5, following is discussed: "When someone jumps from a small boat onto the river bank, why does jumper often fall into water? Explain" (p. 77.) The textbook's approach to critical thinking is primarily embedded in structure of scientific content presentations, problem-solving examples, end-of-chapter questions. It moves beyond mere recall of information to require application, analysis and evaluation. Chapter 9 clearly addresses scientific methods and the process of developing knowledge over hypothesis testing, experimentation, and theory building, providing framework for critical thinking in science. The concept of falsifiability is described in image (p. 189).

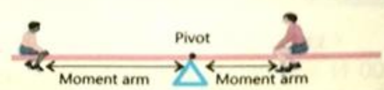
6. Falsifiability
It is a concept introduced that suggests a theory to be considered scientific if it also make predictions that can be tested and potentially proven false. The requirement of falsifiability ensures that theories are not based on vague, non-specific or untestable claims. It distinguishes scientific theories from false or pretended beliefs that cannot be experimentally tested.

The textbook encourages critical evaluation in several sections, although it could further develop skills like systematic evaluation of evidence and identifying assumptions. Many critical thinking opportunities appear in the end-of-chapter questions rather than being integrated throughout the learning process.

Communication

Physics textbooks approach communication primarily as a vehicle for content delivery rather than as a skill to be developed. While it offers explanations of Physics concepts and occasionally prompts students to discuss comments, it lacks guidance on developing scientific communication, elements present in textbook are teacher-directed rather than student-centered, with limited opportunities for students to develop scientific voices. In Activity 4.1 (p. 82), students are asked to work with see-saw and examine balance principles, with instructions to observe what they observe along with the communicate findings.

Activity 4.1
Take your class to play ground where a see-saw is available. Let a lighter child sits on the left side and the heavier one on the right side of the see-saw. The distances of both the children from the pivot should be equal. The force exerted by each child is equal to his weight acting downward. Does the heavier child move down? Yes, because he is exerting larger force. Now move the heavier child nearer to the pivot and the lighter child away from the pivot as shown in the figure. Ask the students what do they observe?



There are few structured opportunities for students to practice communication like scientists, such as constructing evidence-based arguments, critiquing others' reasoning, or presenting findings in formats consistent with scientific practice. In this connection, when communication activities occur, they typically focus upon reporting the observations rather than engaging in the deeper scientific discourse. In the first chapter, activity 1.2 is about the communication, as illustrated in the following image (p. 14).

> **Activity 1.2**
>
> The teacher should facilitate to perform this activity by making groups. Each group should place ten coins one above the other. Record their total height using a metre rule. Divide by 10.
> What is the thickness of one coin?
> Now find the thickness of one coin using Vernier Callipers.
> What is the result?
> Each group should comment on the measurement using the two instruments.

Activity 1.7 is about group formation and facilitation by teachers (p 18).

> **Activity 1.7**
>
> The teacher should facilitate the groups to take a metallic ball or a pendulum bob. Measure its diameter and then volume by placing it in between two wooden blocks alongside a ruler. Then use measuring cylinder and comment on the result of this two onset activities.

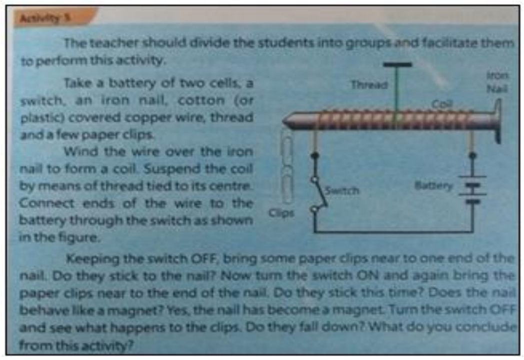
In Chapter 9 scientific method has been described at 9.5 in the following words: "Record, organize and analyze gathered data, plotting and interpreting graphs to reach a conclusion which is called a theory" (p. 187). Also, activity 7.1 (p. 150) directs teachers to "initiate discussion" about temperature concepts when students conduct experiments. This is narrated in the following image extracted from the book.

> **Activity 7.1**
>
> The teacher should arrange hot water in some tea cups, thermometers and metal spoons. Make groups of the students. Each group will put the spoon in the hot water and stir it. Ask them what do they feel. Does the other end of the spoon also become hot?

The textbook explains: "The teacher should facilitate this activity and initiate discussion as per the direction" (p. 7), showing awareness of guided discourse. Still, communication aspects are mostly implicit rather than explicitly taught. The textbooks rarely guide students on how to effectively communicate their scientific understanding, present their findings, engage with scientific discourse. The emphasis remains primarily on the content delivery rather than on developing communication as a skill.

Collaboration

In Physics textbooks, collaboration primarily appears in the form of group activities and laboratory experiments. These provide opportunities for students to work together; however, they follow highly structured procedures with predetermined outcomes rather than inspiring genuine collaborative inquiry or problem-solving. In this linking, the most collaborative activities position the teacher as a facilitator who organizes groups and manages the activity with limited guidance on how students might effectively collaborate in the diverse situations. Activity 7.1 explicitly mentions: "The teacher should arrange hot water in some tea cups, thermometers and metal spoons for groups of students" (p. 150). Activity 5 of Chapter 8 narrates about group discussions with facilitation, as in following image (p. 169).



Activity 5

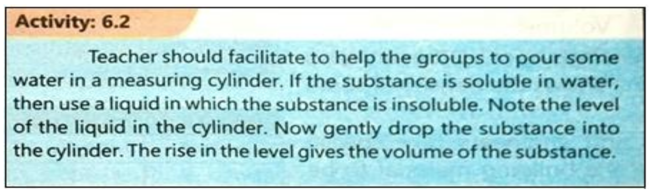
The teacher should divide the students into groups and facilitate them to perform this activity.

Take a battery of two cells, a switch, an iron nail, cotton (or plastic) covered copper wire, thread and a few paper clips.

Wind the wire over the iron nail to form a coil. Suspend the coil by means of thread tied to its centre. Connect ends of the wire to the battery through the switch as shown in the figure.

Keeping the switch OFF, bring some paper clips near to one end of the nail. Do they stick to the nail? Now turn the switch ON and again bring the paper clips near to the end of the nail. Do they stick this time? Does the nail behave like a magnet? Yes, the nail has become a magnet. Turn the switch OFF and see what happens to the clips. Do they fall down? What do you conclude from this activity?

Activity 6.2 is also about the facilitation of the teachers and grouping of students, as illustrated in following image (p. 132).



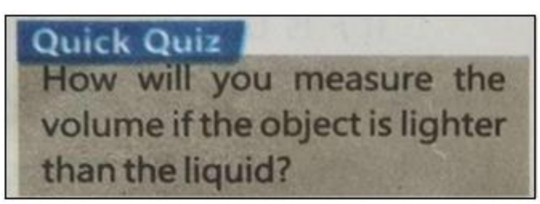
Activity: 6.2

Teacher should facilitate to help the groups to pour some water in a measuring cylinder. If the substance is soluble in water, then use a liquid in which the substance is insoluble. Note the level of the liquid in the cylinder. Now gently drop the substance into the cylinder. The rise in the level gives the volume of the substance.

Although these group activities offer opportunities for collaboration, they follow guided structure with teacher direction instead of exciting student-led collaborative problem-solving, collaborative aspects focus on following procedures rather than developing collaborative strategies, negotiating a shared understanding.

Creativity

The Physics textbook demonstrated minimal emphasis on creativity compared to the other Cs. The predominant approach to science learning is receiving established knowledge instead of creating or constructing the new understanding. In this linking, the laboratory activities and experiments typically follow prescribed procedures with predetermined outcomes, offering limited prospects for students to design their investigations, generate multiple approaches to problem-solving, or engage in open-ended exploration. Activity 1.4 allows for creative design that is narrated in the following way: "The teacher should help each group to make a paper scale having least count 0.2 cm and 0.5 cm," (p. 16). Some Quick Quiz require the creative approaches to solutions, such as in the following image: (p. 131).



Quick Quiz

How will you measure the volume if the object is lighter than the liquid?

The textbook occasionally encourages students to imagine hypothetical scenarios. In constructed response sections of Chapter 3, Section 3.6, it is described in following way: "Imagine that if friction vanishes suddenly from everything, then what could be the scenario of daily life activities?" (p. 77).

However, textbook rarely explicitly inspires students to generate novel ideas, design experiments, or approach problems in multiple ways, activities follow prescribed procedures instead of allowing for creative exploration.

DISCUSSION

The analysis of the Grade IX Physics textbook through the lens of the 4Cs revealed varying degrees of emphasis on these 21st century skills. The textbook demonstrated a stronger emphasis on critical thinking than the other Cs, with numerous chances for students to analyze problems, apply concepts to new situations, and engage in scientific reasoning. This is in concord with traditional approaches in teaching Physics since traditional approaches in the teaching Physics are more inclined towards analytical problem-solving (Tiruneh, Cock & Elen, 2018). However, the identified critical thinking opportunities were mainly of application of concepts learned rather than the analyzing or evaluate type that would require one to critically assess evidence or analyze the credibility of the scientific claim. In this drive, the nature of science is portrayed as a set of discoveries rather than a way of pursuing knowledge. There is a lack of open-ended questions from student's perspective that ask them to critically evaluate and assess one or multiple explanations or to assess the weaknesses of a certain scientific model, strategy that was presented, which may be useful to rally critical thinking (Miri et al., 2007).

There was little direct teaching of communication as a skill in the textbook; this was mostly inferred. Still, there were only a few occasions when students were asked to make observations or explain the outcomes, and the development of scientific discourse was not often directed. This can be indicative of fact that in teaching materials, including those focusing on science disciplines, communication is not treated as rather that needs to be taught but rather as something that will develop along with content gaining as lesser outcome (Tang, 2020). The textbook could better support communication skill growth by incorporating Krajcik and Sutherland (2010) recommended strategies, such as scaffolding scientific argumentation and providing opportunities for students to communicate ideas using multiple representational forms. Collaboration appeared in the form of group activities and laboratory exercises; still, these activities typically tailed structured actions with predetermined outcomes. This approach limits the potential benefits of learning, as found by Graesser et al. (2018), who observed that shared problem solving in science led to better solutions than individual work, for complex problems.

The textbook's collaborative activities resembled what Sampson and Clark (2009) described as the 'procedural collaboration' rather than genuine collective knowledge construction. Thus, enhancing collaborative learning chances requires reshaping activities to integrate positive interdependence, individual accountability, and collective meaning-making. Creativity was the least emphasized of 4Cs, with few opportunities for students to generate novel approaches or design their investigations. This is in consonance with the statement made by Hadzigeorgiou et al. (2012) that creativity, which is a core component in defining and implementing science, has been left out of science education. This agrees with Khalick et al. (2017), who observed that laboratory activities tend to have the full prescription of discoveries, which hinders creativity and innovation in science learning. Therefore, increasing the number of open- and multiple-solution design tasks in textbooks might improve creative thinking.

According to analysis, 4Cs in Physics textbook for Grade IX are not yet fully developed because overall, the content and thinking skills emphasized in the science learning have been more strongly focused on concept and calculation than on communication and cooperation, and even less on creativity (Chiappetta & Fillman, 2007). This deficiency might compromise development of the entire range of competencies required for success in modern scientific environments that demand interdisciplinary cooperation and collaboration, a creative approach to identification of problems and solutions, and fluent communication skills (Levrini et al., 2015). The tendency to include these skills as minor outcomes of learning of content rather than integrating their acquisition as target learning upshot may not equip students with capabilities required in today scientific employment, which requires mastery of all four learning skills. Such results indicate the necessity of reviewing Physics textbooks to achieve focused and coherent integration of 4Cs into each of material subject areas. Instead of viewing these skills as mere acquisitions that come with content knowledge, it is possible to design textbooks to decisively develop 21st century competencies together with content knowledge in Physics.

CONCLUSION

This study conducted through qualitative content analysis facilitated by NVivo 14 identified the extent to which the four 21st century skills, namely, critical thinking, communication, collaboration, and creativity, are addressed in the grade IX Physics textbook published by the Punjab Curriculum and Textbook Board (PCTB). The results show that, as for critical thinking as processes of problem-solving and concept application supported by the textbook, they are rather good; as for critical thinking as the generation of communication, collaboration, and creativity, opportunities are shown to be significantly less scaffolded. Such an imbalance can be recognized in general trend in science education, which focuses on subject content and critical thinking rather than other valuable skills. Given emerging trend in education systems to adopt communication, critical thinking, creativity and collaboration, skills as key skills required in 21st century, Physics teachers and authors should purposefully incorporate 4Cs as they develop new materials. This may include redesigning activities to foster collaboration, incorporating explicit scaffolding for scientific communication, providing more open-ended opportunities for creative problem-solving. Such boosts would better align the Physics education with modern educational frameworks and better prepare students for future academic, proficient challenges that need not only strong content knowledge but well-developed 21st century skills.

Recommendations

1. Laboratory activities should be designed for more open-ended investigations in procedures, propose multiple solutions, and engage in authentic scientific inquiry rather than following prescribed steps.
2. For the scientific communications explicit scaffolding should be incorporated for students' explanation, engagement and motivation in argumentation, and representation of concepts in Physics.

3. Likewise, group activities, from procedural cooperation to substantive collaboration, should be transformed by positive interdependence, individual accountability, and construction of collective knowledge.
4. Critical thinking should be integrated in an inclusive way by balancing algorithm problem-solving with tasks that require the evaluation of evidence, analysis of competing models, and recognition of physics principles.
5. Supplementary teacher resources should be developed to offer explicit guidance on easing 4Cs development with Physics content, helping teachers recognize and leverage chances for 21st century skill development within existing textbook material.

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