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Design and Implementation of Competency-Oriented School Climate Change Education Curricula

Zhao Meiyuyang[1,a,*]

[1]*School of Humanities, Jiangnan University, Wuxi, China*
[a]*1282003628@qq.com*
[*]*Corresponding author*

Abstract: *This article explores the integration of climate change education within school curricula, emphasizing the importance of early environmental awareness. By analyzing current educational practices and policies, the study identifies key areas where climate change topics can be effectively incorporated. The study highlights the role of teachers in fostering a proactive attitude towards environmental stewardship among young students. Through case studies, the article presents successful strategies and challenges faced in implementing climate change education. The findings suggest that a comprehensive approach, combining theoretical knowledge with practical activities, significantly enhances students' understanding and engagement. The study concludes with recommendations for policymakers and educators to support the development of a robust climate change curriculum, aiming to equip the next generation with the knowledge and skills necessary to address environmental challenges.*

Keywords: *Climate Literacy; Competency-Based Education; Curriculum Design; Climate Change Education*

1. Introduction

Since the turn of the century, significant progress has been made in global environmental protection. However, despite these improvements, climate change remains a critical and widely discussed issue. The latest report by the Intergovernmental Panel on Climate Change (IPCC) indicates that the decade from 2011 to 2020 was the warmest on record, with global average temperatures rising approximately 1.09°C above pre-industrial levels[1]. This warming trend continues to exacerbate threats to human survival and development through cascading effects[2]. Education is widely regarded as a moral and cost-effective means of addressing climate change and promoting sustainable development[3]. Given the central role of schools in the educational system[4], school-based climate education should be an essential component of the broader climate education framework. The international community has long emphasized the integration of climate change education into school curricula. For example, the United States' Next Generation Science Standards (NGSS) outline the climate literacy standards that citizens should attain[5], and UNESCO has actively promoted climate change education[6]. With ongoing educational reforms, the focus has shifted to competency-based education. In this context, the reconfiguration of climate education must also be examined from a competency-oriented perspective. What capabilities and knowledge constitute "climate literacy"? How can we design and implement school-based climate change education curricula aligned with competency-oriented principles? These are pressing questions that need to be addressed in the current efforts to reform school climate change education.

2. The Definition of Climate Literacy

Climate literacy is a relatively new concept introduced in the field of science education. Before exploring its concepts and models, it is essential to analyze the term "climate literacy." The word "climate" originates from the Old French "climat," meaning "region" or "part of the Earth," which, in turn, derives from the Latin "clima," meaning "region" or "slope of the Earth." It refers to the overall weather conditions of a region, encompassing variations in heat, cold, rainfall, wind, and other factors. "Literacy" originally referred to the ability to identify, understand, interpret, create, communicate, and use printed and written materials[7]. However, in the context of climate literacy, the term extends beyond written materials, encompassing broader competencies.

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Current definitions of climate literacy can be categorized into two fundamental aspects.

Firstly, there is the scientific aspect. From the perspective of procedural knowledge, climate literacy emphasizes scientific understanding and environmental awareness. This includes knowledge of environmental and climate issues, the ability to apply technology to address climate problems, understanding the impacts of climate change, and a concern for natural resources and environmental quality. For instance, NOAA and scholars like Liu and Xianhua Meng define "climate literacy" as an understanding of the basic principles of the Earth's climate system and the ability to evaluate scientifically credible climate information[8][9][10].

Secondly, there is the social aspect. From the perspective of epistemological knowledge, this aspect emphasizes social responsibility and environmental ethics. It involves ethical considerations and moral reasoning, stressing the importance of social values when addressing climate issues. This includes evaluating the validity of climate information through scientific argumentation[11] and considering ethical and value-based approaches when tackling global climate change challenges[12][13].

According to the climate literacy model proposed by Azevedo and Marques, these scientific and social aspects reflect "two cultures"—scientific education methods and science communication methods. Both approaches aim to address "complexity and conflict," with the shared goal of "education/communication for sustainability." Thus, climate literacy is not merely an accumulation of knowledge but a competence that fosters understanding and action toward sustainability through education and communication[14].

In a nutshell, The current trend in understanding climate literacy is shifting from a focus on simple knowledge, skills, and attitudes to critical individual competencies. These competencies involve acquiring and processing climate information, evaluating and responding to climate change in a global context. The development of these abilities relies on mastering climate knowledge through engagement with real-world climate change situations, transforming knowledge into actionable skills. This is vital for enhancing individual participation in climate change mitigation and cultivating sustainable climate learning abilities. Moreover, it has profound implications for strengthening the overall capacity of nations and societies to address climate change. Therefore, fostering climate literacy should be at the core of school-based climate change education, guiding the design and implementation of educational curricula.

3. The Design of Competency-Oriented School Climate Change Education Curriculum

Educational systems worldwide are increasingly adopting competency-based approaches, and climate change education, as a critical component of this transformation, is also undergoing this shift. Diverse interpretations of climate literacy will inform the varied design of school climate change education curricula. Drawing on a comprehensive analysis of the concept of climate literacy, as well as research and practical outcomes from school climate change education both domestically and internationally, this paper proposes a systematic reconstruction of the school climate change education curriculum framework. This reconstruction should be approached from multiple dimensions, including the establishment of curriculum objectives, selection of content, implementation strategies, and assessment mechanisms.

3.1. Establishing a "Trinity" Curriculum Objective

In relation to the concept of environmental education, climate literacy is conceptualized as a three-dimensional construct—knowledge, skills, and attitudes or values[15]. The curriculum objectives emphasize the comprehensive cultivation of students' climate literacy, encompassing not only a deep understanding of the science of climate change but also the necessary skills and values. At the core of climate literacy is empowering students with the ability to analyze and solve climate issues. This requires them to master relevant scientific principles and technical methods and to develop positive environmental values. Through such curriculum design, students will gain a profound cognitive understanding of how climate systems operate and how human activities impact the climate. On a skill level, they will learn how to apply this knowledge to assess climate change risks and formulate appropriate adaptation and mitigation strategies. More importantly, this curriculum design will emotionally engage students, fostering their concern and empathy for climate change, thereby enhancing their enthusiasm and participation in climate change education. When students emotionally connect with climate issues, they are more likely to take action and contribute at both individual and community levels. Thus, this curriculum design not only educates students about climate change but also plays a crucial role in cultivating them as responsible citizens capable of facing future climate challenges. This comprehensive

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educational approach ensures that students can combine theoretical knowledge with practical activities, ultimately becoming active advocates for climate action.

3.2. Interdisciplinary and Life-Integrated Curriculum Content Design

The interdisciplinary nature of climate change education and its connection to students' daily lives[16] forms the cornerstone of competency-oriented school climate change curricula. As a global issue, climate change involves not only environmental science but also intersects with economics, society, politics, and culture[17]. An interdisciplinary content design helps students understand the complexity and broad impact of climate change from multiple dimensions, laying the foundation for effective response strategies. This approach promotes students' comprehensive development in knowledge, skills, and values, preparing them to become responsible citizens capable of addressing future climate challenges. Climate change education should integrate knowledge from both natural and social sciences, helping students connect disciplines to understand, improve, and implement climate change solutions. For example, studying meteorology enables students to grasp the principles of the climate system, while sociology and economics reveal the impacts of climate change on social structures and economic activities. Ethics guides students in considering issues of climate justice and responsibility. Linking educational content with students' daily lives enhances engagement and practical awareness. Discussing topics such as renewable energy, biodiversity conservation, and climate justice can spark interest and motivate students to take action, making them part of the climate change solution and active advocates for climate action.

3.3. Emotion-Driven Experiential Curriculum Implementation Methods

Experiencing the emotions associated with climate change can enhance individuals' willingness to participate in climate action. Scholars Brownlee, Powell, and Jeffery, in their analysis of factors influencing climate change attitudes and actions, emphasize that climate change education must go beyond cognitive and scientific approaches to engage learners on an "emotional level"[18]. Cutter also argues that climate change education should address the existing beliefs, attitudes, and contexts of specific audiences[19]. Therefore, within competency-oriented climate change education, emotion-driven experiential teaching methods are particularly crucial. These methods not only deepen students' cognitive understanding of climate change but also foster emotional resonance with the issue, increasing the likelihood of transforming understanding into action[20]. Experiential learning enables students to directly experience and explore the impacts of climate change, which can more effectively trigger emotional responses and empathy compared to theoretical learning. Emotional engagement encourages students to adopt more proactive attitudes and behaviors towards climate change. Moreover, emotion-driven teaching methods help students develop a personal sense of responsibility for climate change, influencing their future considerations for environmental sustainability. Thus, emotion-driven experiential teaching methods are essential for fostering comprehensive climate literacy in students, enhancing their knowledge, skills, values, and behavior patterns.

3.4. Diverse Curriculum Evaluation System Incorporating Sustainability Indicators

Evaluation is a critical component of the educational process, offering educators essential insights into curriculum effectiveness and student learning progress. In competency-oriented school climate change education, the role of evaluation is paramount. However, 21st-century learning goals emphasize interdisciplinary and deep learning outcomes[21], which often conflict with traditional evaluation methods that focus on specific and clear outcomes. The interdisciplinary nature of climate change education and the diversity of evaluation goals frequently present challenges in effective curriculum assessment. Given the complexity of climate literacy and climate change education[22][23], evaluation methods must be comprehensive and diverse, capable of assessing students' development in knowledge, skills, and attitudes holistically. They should also consider the feedback function of evaluation on teaching and its impact on student motivation. Consequently, evaluation methods need to be highly flexible and adaptable to meet evolving educational needs and diverse student populations. This necessitates the adoption of innovative evaluation approaches, including formative and summative evaluation, peer and self-evaluation, project-based assessment, multiple intelligences evaluation, emotional and attitudinal evaluation, community engagement feedback, digital tools and analytics, and sustainability indicators. These methods can provide not only quantitative data on student learning outcomes but also insights into students' deep understanding, critical thinking, and emotional engagement. Through such comprehensive evaluation, educators can better gauge the curriculum's impact on students'

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climate literacy and make informed adjustments to improve teaching strategies.

4. The Implementation of Competency-Oriented School Climate Change Education Curriculum

School climate change education in China remains in an exploratory phase, facing the challenge of transitioning from a focus on knowledge, skills, and attitudes to competencies. To facilitate this shift, it is crucial to clearly define climate literacy, understand the key elements of competency-oriented curriculum design, and develop scientifically grounded and practical implementation strategies. Based on an analysis of the unique characteristics of climate change education and insights from previous research, this study proposes that the implementation of a competency-oriented school climate change education curriculum should be coordinated at three levels: national policy support, school curriculum planning, and community and family involvement.

4.1. Enhancing National Top-Level Design and Guidance for Climate Change Education Curricula

Climate change curricula encompass a wide range of interdisciplinary content, including scientific, political, and economic dimensions. Research from various countries indicates that most people possess limited and fragmented knowledge of climate issues[24][25]. Thus, strengthening national-level design and guidance for climate change education is essential. This approach ensures consistency and coherence in educational content while accommodating the uncertainty and complexity inherent in climate knowledge. National coordination can also provide essential training for educators, equipping them with the deep knowledge and skills needed to teach this complex subject effectively. Furthermore, top-level design facilitates horizontal and vertical integration between climate change education and school curricula, enabling students to receive coherent and systematic education on climate change across different disciplines and grade levels. This integrated model not only deepens students' understanding of climate change impacts but also enhances their capacity to take practical actions in daily life, fostering citizens with the competencies needed to address global climate challenges. Both the United Nations Framework Convention on Climate Change and the Paris Agreement emphasize the need for governments to lead climate change education and empowerment initiatives[26][27]. In line with this, China could issue guidelines such as "Climate Change Curriculum Standards" to support schools in developing competency-based climate change education curricula tailored to their specific contexts.

4.2. Enhancing the Systematic Level of Competency-Oriented School Climate Change Education Curricula

An analysis of existing school climate change education curricula [28] reveals that while integrating content is often achievable, the primary challenge lies in enhancing the curriculum's systematic structure. Given the inherently integrative nature of climate literacy, a lack of systematic organization within these curricula can impede the effective development of climate-literate citizens. Stanford University in the United States offers a noteworthy example. The curriculum begins with an exploration of climate and weather, progressively delving into carbon emission sources and sinks, as well as the impacts of climate change on physical and biological systems. It seamlessly integrates concepts from earth, life, and physical sciences, alongside the latest climate system data, fostering students' understanding of the scientific and social implications of climate change. The curriculum covers fundamental concepts of climate and weather, studies the Earth's energy budget with a focus on greenhouse gases—particularly carbon dioxide's heat-absorbing and re-radiating properties, which are crucial for understanding climate change. Students explore carbon emission sources and sinks, gaining an understanding that human activities are the primary drivers of climate change. By analyzing ice core data and other physical datasets, students learn about the physical changes induced by climate change and examine biological system datasets to consider the necessary adaptive measures for humans. Additionally, the curriculum encourages students to reflect on the scientific process and the use of language. The climate change mitigation section further allows students to evaluate and select strategies for reducing carbon dioxide emissions [29].

4.3. Promoting the Integration and Complementarity of Family, Community, and School Climate Change Education Curricula

Global climate change education initiatives highlight the crucial role that family and community environments play, alongside formal school systems, in enhancing adolescents' climate knowledge, understanding, and practical action skills. As Stephens and Graham note, "Climate change education should not be confined to formal educational settings, as most individuals will encounter climate issues outside the traditional classroom. Children and adolescents inevitably learn about climate change through

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various channels, including schools, museums, television, newspapers, the internet, community activities, families, and even their own backyards"[30]. Trott and Weinberg's research further indicates that while students exposed to school-based climate education demonstrate heightened awareness and knowledge of climate change, their ability to translate this knowledge into practical action requires reinforcement[31]. This gap is often bridged by informal education, which, though less structured, employs diverse teaching aids and extracurricular activities such as posters, innovative resources like games and documentaries, performing arts, and climate simulation experiences. These methods convey essential climate-related knowledge, skills, and competencies in engaging and accessible ways. For instance, the theme of International Family Day in 2024, "Family and Climate Change"[32], underscores the significance of family and community initiatives in bolstering climate action. Families can instill the values of climate action and sustainable living through education, providing relevant information, organizing training, and encouraging participation. Thus, the active involvement of families and communities effectively complements school curricula, addressing their limitations and more robustly fostering students' climate literacy.

5. Conclusions

The development and implementation of competency-oriented school climate change education curricula are critical steps toward cultivating climate-literate citizens capable of addressing the complex challenges posed by global climate change. This study underscores the importance of integrating climate literacy into school curricula, emphasizing the holistic development of students' knowledge, skills, and attitudes. By establishing a "trinity" of curriculum objectives, designing interdisciplinary and life-integrated content, utilizing emotion-driven experiential learning methods, and incorporating diverse evaluation strategies, schools can effectively nurture the competencies needed for active participation in climate action.

However, the successful implementation of such curricula requires coordinated efforts across multiple levels. National policy support is essential for providing a coherent framework and guidance for climate change education, ensuring that educators are well-prepared to deliver comprehensive and scientifically grounded instruction. Schools must also enhance the systematic nature of their climate education curricula by drawing on best practices from international examples to create a cohesive and integrated learning experience for students.

Additionally, the role of families and communities in climate change education is indispensable. By complementing formal education with informal learning opportunities and practical experiences, they reinforce the knowledge and competencies acquired in school. This collaborative approach ensures that students not only grasp the complexities of climate change but are also motivated to take meaningful action in their daily lives.

In conclusion, as the global community continues to confront the impacts of climate change, the need for a competency-based approach to climate education becomes increasingly urgent. By reorienting educational practices to focus on cultivating climate literacy, we can equip future generations with the tools and mindsets necessary to contribute to a sustainable and resilient world. This study highlights the imperative of embedding climate literacy at the core of school curricula, thereby fostering a new generation of informed and empowered citizens ready to address the challenges of a changing climate.

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