

Experimenting with Competency-Based Curriculum for Climate Change Education in Koulikoro, Mali

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Abstract

Climate change education is a crucial component of the global response to climate change, playing a vital role in helping African nations adapt to the impacts of climate change. Education effectively provides students with the knowledge, skills, and competencies required to serve as change agents in the fight against climate change. This research employed a quasi-experimental design, utilising a curriculum-based education and green wall, with a pre- and post-test format and quantitative methods to examine the impacts of climate change education on the perceptions of fifth- and sixth-grade pupils regarding the causes, consequences, mitigation, and adaptation to climate change. The findings revealed that fifth and sixth-grade pupils addressed their conflation of weather and climate, as

well as greenhouse gases, with sunlight and ozone layer depletion. In addition, the majority of pupils can enumerate the causes of climate change and determine its impacts as well as the strategies leading to climate change mitigation and adaptation. The innovative green wall and curriculum-based education were successful approaches in educating children about climate change, as their combination has achieved the learning goals. The study serves as an example of multidisciplinary and interdisciplinary approaches in climate change education that can help non-governmental organisations, education policy and decision makers in planning climate change education for early age learners.

Keywords: Climate change, Curriculum-based education, Green Wall and Primary school.

1. Introduction

Climate change (CC) is a pressing global issue that poses significant challenges, particularly for countries like Mali, which rely heavily on agriculture and natural resources for livelihoods (Diallo et al., 2020; Maiga et al., 2022). Mali is affected by the impacts of CC, such as repeated droughts, floods, strong winds, bushfires, and destabilisation of the rainfall regime (Gouvernement du Mali, 2015). Children in West and Central Africa are globally the most vulnerable to extreme heat days and have had the most substantial rise in extreme heat over time. Currently, 123 million children experience temperatures over 35 °C, with these regions accounting for 39% (UNICEF, 2024). In Zimbabwe, adverse weather has been linked to the destruction of infrastructure, including bridges, roads, and schools. The dropout rate escalates when residences are obliterated, pupils are unable to traverse bridges to reach educational institutions, and individuals are relocated to safer areas, resulting in the removal of children from schools (Zimbabwe Human Development Report, 2017). Adverse meteorological circumstances influence teachers' motivation to labour in areas susceptible to flooding or drought, hence undermining the quality of teaching (Zimbabwe Human Development Report, 2017). The Office for the Coordination of Humanitarian Affairs (OCHA) stated that since July 2024, Mali has been experiencing exceptional rainfall, the heaviest since 1967, which has caused significant flooding in almost all regions of the country, where many schools have been used to relocate the populations (OCHA, 2024). Torrential rains and overflowing rivers have caused considerable material and human damage across Mali in 2024. Many schools have been requisitioned as emergency shelters for the victims. Faced with this exceptional situation, the decision was made to postpone the start of the school year from October to November (Hamana, 2024). The heatwave led to the reorganisation of the timetable of primary and lower secondary schools, resulting in a one-hour reduction as adaptation strategies for both students and teachers since 2019 (Diawara, 2019). According to the IPCC 2022 report, limiting global warming to 1.5°C is not safe for all, and additionally, 350 million people will face water scarcity by 2030. The water scarcity and other naturally triggered issues in people's lives will ultimately affect the growth and educational potential of the children (Szopa et al., 2021).

Therefore, Anderson (2010) stated that education is the most crucial tool for successful mitigation and adaptation to CC. In these views, addressing the risks of CC and resolving the issues from an early stage is vital for the ongoing development and education of children. The increasing exposure of Mali to droughts, floods, heatwaves and changing weather patterns (Cedric & Krampe, 2021) underscores the urgent need for education systems to play a proactive role in building resilience. In this context, climate change education (CCE) emerges as a crucial strategy not only for raising awareness but also for equipping learners with the competencies required to understand, respond to, and mitigate climate risks. Even though various trends have emerged in CCE in Mali, reflecting a growing recognition of its importance across different levels of society (International Climate Initiative, 2019; Diagne, 2023; UNESCO, 2025). However, gaps remain in formal education, particularly at the primary school level, in terms of intervention regarding CC. This age group represents a critical window for fostering long-term behavioural and attitudinal change. The current study addresses these gaps by experimenting with an innovative tool in curriculum-based education to educate fifth and sixth-grade children about CC-related issues in Mali.

Participatory learning and digital learning have been applied to disseminate CC among young people in Mali (Sanga et al., 2021; International Climate Initiative, 2025). These initiatives are crucial in promoting engagement and fostering a culture of CC and environmental stewardship among youth. Despite these positive trends, several challenges remain in the field of CCE among primary school children in Mali (Sanogo et al., 2020; Tounkara & Soudani, 2024). Limited pedagogical resources, inadequate training for teachers, lack of electricity and insufficient infrastructure (UNESCO, 2020; Sidibé et al., 2022) can hinder the effective delivery of CCE. Moreover, there is a need for innovative, low-cost teaching materials that can be used to teach about CC, such as a green wall. The green wall involves designing CC-related issues on the classroom walls, which can be used to deliver CC lessons to school children.

Looking forward, the establishment of stronger policies that mandate CCE, increased investment in teacher training, and enhanced collaboration among stakeholders are vital for sustained progress. This study aims to evaluate impacts of green wall and curriculum-based CCE among fifth and sixth-grade pupils of Koulikoro, Mali. Moreover, by the end of the CCE intervention, fifth- and sixth-grade pupils must be able to: (i) define CC; (ii) describe greenhouse gases and their effects; (iii) cite the causes of CC; (iv) determine the impacts of CC; and (v) determine mitigation and adaptation measures of CC. The study primarily focused on Sustainable Development Goals (SDGs) 4: Quality Education and 13: Climate Action. Scientifically, the study seeks to achieve the following objectives:

- (i) examine the perceptions of fifth- and sixth-grade pupils regarding climate change causes, impacts, mitigation, and adaptation strategies.
- (ii) assess teachers' views about climate change in the syllabus of fifth and sixth-grade pupils.
- (iii) examine the effects of climate change education on fifth- and sixth-grade pupils regarding their perceptions of climate change causes, impacts, mitigation, and adaptation.

1.1 Students' and Teachers' Perceptions of Climate Change

The young learners' perceptions of the environmental crisis are vital for acting against it. The literature revealed students' variable views about CC-related issues. Several researchers underscore students' attitudes and awareness of CC. For instance, Tunji-Olayeni et al. (2021) investigate CC awareness among secondary school students in Ota, Nigeria, to guide CC mitigation strategies and practices among young people and help them attain the SDGs. The study finds that students are aware of CC, with their schools being the most common source of CCK. The most reported CC effects include a rise in global temperatures, melting ice, flooding, rising sea levels, drought, extinction of terrestrial and marine life, and health challenges and mitigation strategies, including awareness, tree planting, the use of low-carbon vehicles, the use of energy-saving bulbs, the reduction of carbon emissions, and waste recycling. The findings demonstrate that formal education is essential for raising awareness and preparing future leaders in CC mitigation. Chairunnisa et al. (2022) examine Palembang City's junior high school students' knowledge, beliefs, and attitudes on CC in Indonesia. The findings reveal that most students (65.7%) had initial knowledge of CC, 65.5% understood its causes and consequences, and 69.5% showed attitudes towards CC mitigation. It is opined by 34.5% of the students that the general media influence pupils' beliefs and opinions about CC. The study concludes that most junior high school students in Palembang City believe that CC is happening and that these changes threaten humanity's safety. Students also feel that CC has increased the likelihood of forest fires, water shortages, river overflows, stronger storms, and flooding. Sjöblom et al. (2022) explore Finnish and Tanzanian primary students' views on CC. The findings reveal parallels as well as disparities in the pupils' views. According to the findings, most pupils understand the gravity of the CC crisis. In both countries, pupils had varied ideas and beliefs towards the causes and implications of CC. Tanzanian pupils have experienced the consequences of CC and are familiar with them daily. As a result, their responses to questions about the effects of CC are more comprehensive and relevant to the students' real-life experiences than the Finnish students' answers. When the students discussed CC mitigation, the Finnish students mainly focused on what they could do individually immediately, while they emphasise acts involved in changing consumption patterns; Tanzanian students saw opportunities in education and research as well as their roles in becoming educated. Kutwayo et al. (2022) assess secondary school students' CC knowledge, concerns and experiences in South Africa. The findings show that 72.0% of respondents was aware that CC causes greater temperatures, 60.0% agreed that human activity is to blame for CC, and 58.0% believed CC impacts human health. Two-thirds (69.0%) of respondents consider CC a severe issue, and 66.0% believe action is required to avert it. A significant number of students seem unaware of the fact that CC endangers their future. Ramos et al. (2023) study how schoolchildren aged 9 and 13 perceive CC impacts in northeastern Portugal. The results suggest that most children (42%) expressed concern about CC. However, 33.5% of children reported the inability to name just one consequence of CC. Additionally, there were differences between the two grades. For example, sixth-grade children had a higher average understanding of the phenomenon ($p = 0.049$). The parents' educational attainment was positively associated with a more ecocentric posture. According to the data, 46.6% of students say that television is where they learn more about CC. Wadson et al. (2023) examine senior secondary school learners' knowledge, attitudes, and practices regarding CCE content. The findings show that 56.9% of students have negligible knowledge of CC. Regarding attitudes, 73.4% agree that knowing CC content makes individuals concerned about the environment. An average of 66.9% of the students lack various CC strategies for reducing and adapting to CC.

The literature reveals several studies focused on teachers' awareness and views about CC. Therefore, the studies of Li et al. (2019) utilise educational curriculum guidelines and effectiveness strategies to create a secondary instructional resource. They aim to understand and assess changes in teacher efficacy related to CC through an innovative professional development framework. The results indicate that professional development improves self-

efficacy, whereas pedagogical content knowledge provides numerous advantages for educators, particularly those lacking expertise in teaching CC. The study of Boco and Malindog (2020) focus on identifying teachers' misconceptions about CC, their opinions about how it should be incorporated into the grade 8 science curriculum in the Philippines, which specific curriculum topics help teachers integrate the idea of CC, and which instructional resources they use to facilitate this integration. The findings show that teachers have misconceptions about CC. The CC focus is limited in the curriculum. The participants recommended adding a distinct subject to the curriculum. However, they do not favour incorporating CC into every subject, such as science, English, or Filipino. The teacher responders consistently employed media literacy, the lecture-discussion technique, and books and models as teaching resources. Dorji et al. (2021) analyse teachers' knowledge of CC causes, impacts, and mitigation from high secondary schools in Bhutan. Findings show that teachers' awareness of CC is medium; they are more concerned with its effects than its causes and mitigation. Moreover, teaching field, educational attainment, and seminar attendance have significantly impacted teachers' CC awareness. The data suggest that raising awareness of CC can be achieved through improving education, adding environmental studies to the curriculum, and encouraging seminars and workshops on environmental issues. Winter et al. (2022) provide practical advice on harnessing the unrealised potential of CCE, overcoming challenges, and identifying the changes required to enhance existing CCE environments. According to the findings, preservice teachers believe they are not sufficiently prepared for their potential role as “change agents”. They cite a lack of time dedicated to the topic, a lack of engagement with real-world examples of climate action, and a cursory study of the subject. The participants lack support from educational institutions for professional development as change agents. They suggest that teacher preparation programs must emphasise educators' professional growth in CCE. Karim et al. (2022) explore the depth of CC and environmental education in Malaysia's present curriculum from the teachers' perspective. Therefore, the findings generated five themes: educator capacity building, youth empowerment and mobilisation, speeding local-level efforts, and policy advancement. Most teachers thought the Secondary School Standards-based Curriculum had improved, but that the emphasis should be on a student-centred approach rather than exam orientation.

2. Methodology

2.1 Study population and Setting

This study was conducted in Koulikoro city, the second administrative region of Mali. The city is located on the left bank of the Niger River, 60 km northeast of Bamako, by the national road (RN) 27. It extends over the plain on the banks of the river, overlooked by a plateau, an extension of the Manding Mountains called the *Niana Koulou* (Rapport de Koulikoro, 2023). The study was undertaken in two primary schools, which were conveniently selected by the Pedagogic Animation Centre (CAP) of Koulikoro due to their accessibility and the availability of staff for researchers. The schools included were the Primary school “C” in the Lassana Fofana of the Koulikoro school group, which enrolls about 300 pupils annually, and the Primary school Bachaka Keita, which enrolls about 400 students.

Participants were selected from grades 5 and 6 (ages 11-12), as these pupils are the oldest academic year of primary school. Therefore, they can understand the complex environmental concepts raised in this study. Using the Raosoft (2004) sample size determination formula presented below, a sample size of 114 pupils was calculated, among a population of 160, with a 95% confidence interval and a 5% margin of error.

We compiled a list of the population for each class. We randomly selected a sample by name, following the sample frame and the established selection criteria outlined in Article 34 of the primary education law, which stipulates that a child must start school at the age of six. Furthermore, the sample comprises 54 pupils from a public school: 30 fifth-grade pupils (15 boys and 15 girls), and 24 sixth-grade pupils (11 boys and 13 girls). We randomly selected 60 pupils from the private school, 30 from each grade, including 15 boys and 15 girls. Considering the research sample of 114 pupils, 58 were females (50.9%), and 56 were males (49.9%). The Raosoft (2004) sample determination formula used for the sampling is presented below.

$$\begin{aligned}
 X &= Z \left(\frac{C}{100} \right)^2 r(100-r) \\
 n &= Nx / ((N - 1)E^2 + x) \\
 E &= \text{Sqrt}[(n - p) x / n(N - 1)]
 \end{aligned}
 \tag{1}$$

Where: N = Population size, r = responses, Z (C/100) = critical value and C = confidence level.

This study employs a quasi-experimental design comprising a pre-test, instruction, and post-test (Bofferding & Kloser, 2015; Stevenson et al., 2018; Kolenatý et al., 2022; Ghazy & Fathy, 2023) to examine the effectiveness of an innovative approach of green wall with the competency-based curriculum in climate change education (CCE) among primary school pupils. This study uses descriptive statistics to analyse the findings. The study was conducted in two primary schools in Koulikoro, one public and one private, purposively selected by the Pedagogic Animation Centre of Koulikoro (CAP). These schools were selected based on their access and capacity to handle research activities. The selection aimed to represent diverse educational settings. However, this study did not compare these two types of schools regarding climate change (CC). The difference between these schools is the fact that public schools use both french and local languages, and private schools use only french. However, there was no difference in terms of intervention among schools. The intervention involved the implementation of a competency-based curriculum and a “green wall” as a pedagogical tool, a classroom wall design that visually presents CC concepts through different pictures. The competency-based curriculum in the context of this study led to the structure of the Malian primary education curriculum. The curriculum of primary school is structured into five domains of competencies, such as Arts, Human sciences (HS), languages and communication (LC), Personal development (PD) and Sciences, mathematics and technology (SMT). Therefore, CC-related topics were integrated into the subjects of each domain of competency. Moreover, the reason to apply an innovative green wall in this study is the fact that schools lack electricity and teaching and learning materials to educate children successfully. Therefore, integrating CC into the existing curriculum required the provision of resources. The green wall is used to substitute visual tools for CCE, such as e-learning. Once the classroom wall is designed around CC-related issues, it becomes a low-cost solution. It will remain effective for a long time, eliminating the need for paper posters and electricity for visualising CC-related issues among primary school children. The green wall was designed to facilitate hands-on, experimental learning and encourage discussions, fostering a deeper understanding of CC and its local impacts.

2.2 Climate Change Education Intervention

The model of this educational intervention was “the teaching across the subjects”, “in which students encounter climate change (CC) in multiple ways from multiple disciplinary perspectives, with the opportunity to meaningfully integrate these learnings across disciplines” (Iyengar & Kwauk, 2021, p.10). Therefore, climate change education (CCE) topics were incorporated into five domains of competency in primary school curriculum throughout the schooling years, such as the arts, LC, HS, PD and SMT. The CCE is included in the subjects drawing and dramatisation of the Arts domain, with topics that involve drawing a pattern related to the geography lesson on bushfires, singing local and national songs about bushfires, floods, charcoal production, planting trees, drought, and desertification, and dramatising the benefits of micro-dams and the impact of desertification. The subjects of reading and text study in the LC domain encompass topics such as disaster risk management, desertification, reforestation, Africa's savannahs, forests, water, and trees, as well as their value in a changing climate. The subjects of civic education and moral education in the PD domain include pupils' understanding of their environment and its importance, and participating in environmental protection and restoration, ultimately leading to CC mitigation and adaptation. The subjects of geography and history in the HS domain: topics included rising temperatures on the Earth's surface, rising sea levels, natural disasters (such as tornadoes, cyclones, floods, and droughts), and declining agricultural production. Climate variables include temperature, wind, rainfall, pressure, and CC causes, impacts, mitigation, and adaptation strategies. The subject of technology and natural sciences in SMT focused on topics on human air pollution, the manifestations and “effects of greenhouse gases” on nature, the cause of increasing greenhouse gases, and atmospheric pressure; Climate variables, such as temperature, rainfall, wind, and pressure; CC causes, impacts, mitigation and adaptation strategies; disaster risk management; and risk factors for a catastrophe: hazards, stakes, and vulnerability. These were supported by an innovative “green wall” in the classroom about CC-related topics. The National Ministry of Education (MEN) and its partners, including the Ministry of Environment, Sanitation, and Sustainable Development (MEADD) and UNESCO, developed a CCE curriculum over eleven months, from January 2023 to November 2023. The role of the researchers was to assist and follow up on the progress of the activities. Therefore, future studies may discuss the process of curriculum development. The CCE programme started on January 22, 2024, and ended on May 17, 2024.

- **Green Wall**

The green wall addressed several CC-related issues, including the water cycle, causes, impacts, mitigation, and adaptation. Renewable energy sources, including solar, biomass, hydropower, and wind, were also included in the design. Given the limited teaching infrastructure for climate change (CC), the researcher has introduced the green wall as an innovative tool to facilitate classroom activities on the subject. The research team approved the pictures of the green wall and designed them in the classroom. The designing activities were assisted and controlled by school directors. A “green wall” was adopted in the classrooms to illustrate CC-related topics. The green wall addressed

several CC issues, including the water cycle, causes, impacts, mitigation, and adaptation. Renewable energy sources, including solar, biomass, hydropower, and wind, were also included in the design. Figure 1 shows pictures of a green wall constructed using plates. Plate 1 features a discussion between a lumberjack (representing local people or a parent) and a pupil about the impacts of cutting down trees, which can affect the water cycle and lead to flooding. Plate 2 illustrates the effects of CC on people's lives. Drought has affected cows, trees, and land. It also illustrates people's migrations. Plate 3 illustrates the impact of strong winds on buildings, trees, and people, as well as the implications for their materials. Plate 4 describes strategies for mitigating and adapting to CC, including measures to combat floods, drought, desertification, and pollution, utilising stone barrier techniques, hedgerows, reforestation, and afforestation. Plate 5 illustrates two local stoves. The improved stove cooking method reduces the amount of wood consumed for cooking, reducing the need to cut down trees. Plate 6 illustrates CC mitigation through renewable energy sources, including solar, wind, hydraulic, and biomass.



Figure 1: Green wall adopted in the classrooms

2.3 Professional development for teachers

Professional development prepares teachers to recognise and address the emotions that young people experience while learning about climate change (CC) (Rushton et al., 2023). In this study, the teacher participants were engaged in forty (40) hours of professional development about CC. The training was divided into three sessions: simulation of CC, lesson development, and climate change education (CCE) lessons. Therefore, in the study, there were four generalist teachers in charge of their respective classes (grades 5 and 6) throughout the year. Together, thirteen (13) teachers were trained, of which seven (07) were lower secondary, including four social sciences teachers, three natural sciences teachers, and two physics and chemistry school teachers; the next study will be focused on them. The researcher developed the modules for teacher professional development with the Department of School Programmes at the Malian MEN. The researcher conducted a teachers' training session from 14 October 2023 to 14 January 2024. In the first phase, within twenty (20) hours, the teachers were trained on CC,

which enabled them to understand the concepts underlying climate sciences and the causes of CC, both natural and anthropogenic. It also enabled teachers to grasp the concept of resilience in the face of disasters and the techniques for mitigation and adaptation to the effects of CC. The second training session was carried out in ten (10) hours. It involved defining sub-themes within the themes developed in the first session, with a focus on CC and related issues. This session guided the adoption of CC concepts and the development of teaching/learning content related to CC-related problems linked with the five competency domains. The third training session lasted ten (10) hours, during which the teachers engaged in a CCE lesson simulation. During this session, building on previous sessions, the teachers developed and presented lesson models that pupils could learn from, with the hope that they would act on these lessons in their communities. Following their capacity building, teachers taught the CCE programme in their respective classes from January 22, 2024, to May 17, 2024.

2.4 Evaluation

The target groups in this research consist of fifth- and sixth-grade pupils from primary schools. The experimental process involved three main phases:

- Pre-intervention data collection on pupils' climate definition, views on greenhouse gases and perceptions of causes, impacts, mitigation and adaptation.
- Implementation of the climate change education with the integrated competency-based curriculum and green wall as a central pedagogical tool.
- Evaluation of changes in pupils' views and perceptions of climate change following the educational intervention.

• *Survey and Interview*

Self-reported questionnaire structured into three parts and included sections (A to C) to assess pupils' understanding of CC, covering definitions of CC, perceptions of CC, causes, impacts, mitigation, and adaptation. Section A elicited information about gender, age, type of school, and grade. Section B focused on pupils' beliefs about the concept of CC. In this section, pupils were asked to share their understanding of CC based on their experiences and perspectives. This section also included three multiple-choice questions about greenhouse gases and their effects. Section C focused on perceptions of CC, structured into four subsections. Twelve (12) perception statements were included in the causes of CC in section C1. In Section C2, the questionnaire contained nine (9) items to assess pupils' perceptions of the impacts of CC. To examine pupils' understanding of CC mitigation, the questionnaire provided ten (10) perception statements in section C3. In the next section, Section C4, eight (8) items were used to assess pupils' perceptions regarding the adaptation of CC. A Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) measured the perception statements of fifth and sixth-grade pupils regarding CC related-issues.

To explore teachers' views on CC-related issues in the syllabus of their pupils, the researchers conducted a focus group on the status of CC-related issues in the subjects of the five competency domains of the curriculum, including LC, HS, PD, SMT, and Arts. The teachers' capacities for teaching about CC were also addressed in the interview. The focus group discussion (FGD) for this study was conducted with the thirteen teachers who have participated in professional development. Therefore, four (04) focus group discussions were conducted, three groups of four teachers (FGD1, FGD2, FGD3) and one group of five teachers (FGD4). The teachers were identified by number within the group, such as teacher 1 and teacher 2, according to the number of teachers in the FGD. The findings from the four primary school teachers are reported in this study.

According to Kimberlin and Winterstein (2008), validity assesses the accuracy of a quantitative study, whereas reliability evaluates its consistency. These qualities were achieved through the use of a carefully constructed questionnaires developed and reviewed by four professionals: an associate professor from Taraba State University in Nigeria, a professor from Hamburg University of Applied Sciences in Germany, a professor from the University of Cape Coast in Ghana, and a professor from the Institut Polytechnique Rural de Formation et de Recherche Appliquée de Katibougou in Mali. After obtaining approval, the survey questionnaire was pilot tested on 10% of the study sample from two primary schools at the Pedagogical Animation Centre of Sogoniko, Bamako. Moreover, several recommendations were incorporated into the final version of this study. Internal consistency was assessed using the Cronbach's alpha scale coefficient, and a value of 90% was attained, surpassing the 50% threshold considered appropriate by previous investigations (Bagozzi & Yi, 1988; Cronbach, 1951; Cronbach & Shavelson, 2004).

2.5 Data Collection and Data Analysis

Pre-education data were collected in November 2023, and post-education data were collected in May and June 2024. Trained enumerators, fluent in both french and *Bamanankan*, facilitated the survey to ensure clear

communication and understanding. The pre-intervention phase assessed pupils' initial definitions, perceptions of climate change (CC) causes, impacts, mitigation and adaptation. During the intervention, the green wall was introduced as a central teaching tool, integrated into regular classroom activities jointly with an integrated curriculum with CC. Post-intervention data collection followed the same structured questionnaire to evaluate changes in climate-related perception statements.

Data was extracted and arranged in a single spreadsheet with the questions and responses for each section. The spreadsheet containing the questionnaire answers was imported into RStudio version 4.1.2 software for analysis. Primarily, the items in each section were self-computed into unique variables, except for the multiple-choice questions in section B. Pupils' definitions of CC from section B were compared to those of IPCC. Therefore, the perceptions of fifth and sixth-grade pupils regarding CC were descriptively presented using frequencies and percentages.

- **Ethics Statements**

Ethical approval for this study was obtained from the Ethics Committee of the Pedagogic Animation Centre (CAP) in Koulikoro. The study adheres to national and international ethical standards relevant to educational research in Mali. A parental consent letter was explained to the parents. The pupils' informative letter was orally given to them. To ensure confidentiality, the study did not record the names or residential information of the participants. Additionally, the questions were translated and delivered in both french and *Bamanankan*, the primary languages spoken in the study area.

3. Results

3.1 Teachers' views about climate change in their syllabus

Teachers' focus group discussion (FGD) findings indicate that they concur that the school curriculum insufficiently addresses climate change issues. As presented in the following quotations, the teachers claimed that the current syllabus lacks topics about climate change and there are limited resources and capacity among teachers to teach on the subject.

In the subject of moral and civic education in both grades 5 and 6, *“explicitly, there is no climate change itself in the syllabus of fifth and sixth grade. However, there are topics of environmental education of which we can address education about climate change, such as sanitation of the school environment, as well as cleanliness of the body. Moreover, we recognised that there are topics related to deforestation and tree plantation”* (FGD4-teacher 1, FGD2-teacher 3).

The fifth and sixth grade teachers claimed that: *“in our school, there is a lack of suitable materials to demonstrate climate change-related topics to pupils effectively. If I instruct on climate change based solely on the material found in the textbook, my pupils will not understand the subject. The lessons about climate change-related issues, such as crop rotation, deforestation and agriculture, are found at the end of the year in the natural sciences subject”* (FGD 3-teacher 2-, FGD 4-teacher 1).

Moreover, the primary school teachers emphasised: *“as a geography and French teacher, I know the syllabus does not mention CC. However, focusing on some topics may lead to climate change education, including the disappearance of vegetation cover, water pollution, desertification, and unsanitary conditions, which are found in the syllabus of grades 5 and 6. However, I could not go further about it; otherwise, I would leave content that is a priority for students. The national ministry of education should prioritise them and train the teachers with adequate resources”* (FGD2- teacher 3, FGD1- teacher 4).

3.2 Fifth- and Sixth-Grade Pupils' Definition of Climate Change

The definitions provided by the teachers were compared to those proposed by IPCC, which defines “climate change” as “any change in climate over time, whether due to natural variability or as a result of human activity” (Folland et al., 2001, p.22). An assessment criterion (Havea, 2021) delineated the standards for evaluating pupils' definitions. A score of three was granted for a participant who cited three out of four items, two for two items and one for a single item mentioned. Pupils who failed to address the four criteria or offered irrelevant comments and divergent perspectives on CC were assigned a score of 0.

The pretest results indicated that none of the 114 respondents incorporated up to three or four expected items in their definitions. Seven children incorporated two items in their definitions; nine pupils referenced only one, while 98 pupils omitted mention of any of them. These 98 pupils included misconceptions or irrelevant responses on CC in their definitions. However, in Table 1, the findings from the posttest showed that most respondents included some items in their definition of CC. Sixty-eight out of 114 pupils included one item, 20 mentioned two items, and 18 included three. The fifth and sixth graders considered CC “modifying weather patterns recorded for 30 years or

more.” Human activities mainly influence it, and it affects people and their livelihoods. They indicated that “CC is the change in weather conditions, the day-to-day average around the atmosphere,” which occurs naturally but is increased by human activities. However, in the last category, eight pupils mentioned alternative conceptions or irrelevant answers to what was required.

Table 1: Fifth- and Sixth-Grade Pupils’ Definition of Climate Change compared to IPCC’s Definition (n=114)

List of items	Grading grid									
	Pupils cite four items from the list below		Pupils cite three items from the list below		Pupils cite two items from the list below		Pupils cite one item from the list below		Pupils do not cite any of the list below	
Test	Pre	post	pre	post	pre	post	pre	post	pre	post
Count	0		0	18	7	20	9	68	98	8

Note: Expected response: “Change in climate over time, Result of natural process, Result of human activity, Impact.”

Table 2 explicitly shows that 86.0% of the pupils reported alternative conceptions of climate change (CC). According to them, CC is moving from the rainy to the dry season. Some also considered it as changing from the cold to the hot season. Also, 6.1% of pupils' definitions revealed impacts and causes, including waste (industrial and household) thrown in the river Niger and reduction in water supplies and resources. Furthermore, 4.4% of pupils' definitions included rising temperatures during the dry season and a lack of rain during the rainy season, while 3.5% of pupils cited that deforestation contributes more to CC. The post-assessment revealed that 43.0% of respondents mentioned the “causes of CC” in their definitions. The pupils mainly focused on cutting down trees, firewood production, industrial activities, waste and river sand mining as causes of CC. About 33.0% of respondents mentioned the “impacts of CC”, including rising temperatures, flooding, droughts, air pollution and water pollution. Moreover, 16.7% of pupils mentioned both CC causes and impacts. Some noted that cutting down trees and charcoal production could increase temperature, and wastes could pollute water and air and degrade the environment. However, seven per cent (7.0%) of respondents continued to indicate that they did not comprehend the concept of CC, even though it is changing the seasons from rainy to dry.

Table 2: Fifth- and Sixth Grade Pupils’ Definitions of CC Presented by Category (n=114).

Category	Pre-test		Post-test		
	Items	Freq.	%	Freq.	%
Impacts		5	4.4	38	33.3
Causes		4	3.5	49	43.0
Impacts and causes		7	6.1	19	16.7
Alternative conceptions and irrelevant responses		98	86.0	8	7.0

Note: Alternative conceptions reported by pupils were more rainfall or less rainfall during the rainy season, June to October, and higher temperature during the hot season, March to May. Irrelevant answers reported by pupils were changing from day to night and from season to season, including dry, rainy, cold, and hot weather.

3.3 Fifth- and Sixth-Grade Pupils’ Responses about Greenhouse gases

Table 3 explicitly illustrates that fifth- and sixth-grade pupils require assistance in comprehending the “human contribution to the current increase of carbon dioxide in the atmosphere”, with 20.2% of pupils stating in the pre-test and 97.5% in the post-test that “increased carbon dioxide is due to humans using more fossil fuels”. Moreover, most pupils must understand the rationale behind the “rise in global temperatures.” Before the intervention, only 28.1% of pupils knew that “global temperatures” are increasing because of increased carbon dioxide from burning fossil fuels, compared to 91.3% of respondents after the intervention. In contrast, in the first assessment, most pupils, 43.9%, reported that the global temperature is due to “the sun releasing more heat energy,” and 29.8% of pupils chose that increased “global temperatures” are caused by excess heat “from energy generation in power stations.” However, in the post-test, only 2.5% emphasised sunlight and plants releasing gases as contributors to global temperatures. According to 25.4% of pupils, the global temperature rise occurs when “a hole in the ozone layer” allows “heat to enter the Earth’s atmosphere” in their pre-test view; however, after educational activities on CC, only 8.7% of fifth and sixth-grade pupils indicated “a hole in the ozone layer allows heat to enter the earth’s atmosphere” as cause for rising global temperatures. From the pre-test assessment, 21.9% of fifth- and sixth-grade pupils accurately identified

that “water vapour, carbon dioxide, methane, and nitrous oxide” are greenhouse gases. About 34.2% of pupils stated that they are “solar gases”, 31.6% responded that these are “ozone gases”, and 12.3% believed that these gases are called “atmospheric gases”. Comparatively, the post-education findings showed that most pupils, 94.8%, stated that “greenhouse gases”, such as “carbon dioxide, methane, nitrous oxide, and water vapour”, regulate Earth’s temperature and climate.

Table 3: Fifth- and Sixth-Grade Pupils’ Responses About Greenhouse Gases (114).

Questions	Response options (correct answer is in bold)	%	
		Pre-test	Post-test
What is the most likely cause of the current increase in carbon dioxide?	a. Plants release more carbon dioxide b. The sun releases more thermal energy c. Earth's orbit around the Sun is changing d. Humans are generating more and more air pollution	20.2	97.5
What do scientists believe has led to the increase in global temperature?	a. Excess heat is released by energy production in power plants b. Increased use of toxic chemicals such as spray pesticides c. A hole in the ozone layer allows heat to enter the Earth's atmosphere d. Increase in the amount of carbon dioxide (CO₂) from the burning of fossil fuels	28.1	91.3
What are the names of atmospheric gases: water vapor, carbon dioxide, methane, and nitrous oxide that help maintain Earth's temperatures and climate?	a. Ozone gas b. Solar gases c. Greenhouse gases d. Atmospheric gases	21.9	94.8

3.4 Fifth- and Sixth-Grade Pupils’ Perceptions of Climate Change

This section investigated fifth- and sixth-graders' perceptions of climate change (CC) causes, impacts, mitigation, and adaptation. Table 4 explicitly shows that 93.86% of the fifth- and sixth-grade pupils had a neutral view of the causes of CC included in the questionnaire. From the post-test, 97.4% of fifth and sixth-grade pupils agreed that CC is caused by burning fossil fuels, deforestation, waste (domestic and agricultural), and cooling devices such as air conditioners. Table 4 demonstrates that 96.5% of the pupils were neutral, indicating a lack of general knowledge of the consequences of CC in the pre-test. Still, the post-test findings showed that 97.4% of pupils agreed with the consequences of CC, including floods, droughts, reduced food production, pollution of air and water, and damage to forests and wildlife. Regarding carbon capture mitigation, 97.4% of the pupils reported neutral regarding the mitigation strategies in the pretest. This indicates that in the pretest, fifth- and sixth-grade pupils did not understand CC mitigation strategies, including renewable energy, wildlife conservation, agroforestry, afforestation, waste management, compost, and pesticide manufacture. In the post-test, 100.0% of pupils' responses agreed with these measures. Pupils' perceptions of CC adaptation were assessed in a pre-test, where 97% of respondents reported neutral to the claims. This implies that pupils have a limited understanding of CC adaptation strategies, including climate-smart agriculture (half-moon, crop rotation, intercropping, zai, half-moon and stone barriers), windbreak techniques, septic systems, water harvesting for irrigation, and awareness-raising strategies; however, the post-test results show that 96.5% of pupils agreed with these CC adaptation measures.

Table 4: Fifth- and Sixth-Grade Pupils' Views about Climate Change (n=114).

Responses <i>Test</i>	Causes		Impacts		Mitigation		Adaptation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Scale	%	%	%	%	%	%	%	%
Strongly disagree	0.0	0	0.0	0	0.0	0	0.0	0
Disagree	6.1	0	6.1	0	2.4	0	2.4	0
Neutral	93.9	2.6	93.9	1.7	96.5	0	97.4	2.6
Agree	0.0	97.4	0.0	97.4	0.9	100	0.0	96.5

Strongly agree	0.0	0	0.0	0.9	0	0	0.0	0
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4. Discussion

This study experimented with an innovative teaching learning tool with an integrated curriculum within the framework of five competency domains. It was implemented with topics included in the existing curriculum. The study aims to evaluate the impacts of green walls and curriculum-based CCE among fifth and sixth-grade pupils of Koulikoro, Mali.

Firstly, at the end of this study, most fifth and sixth-grade pupils can define CC from their learning experiences. According to the findings, they believe CC raises the average temperatures over long periods due to human activity and natural processes that significantly impact the environment, people, and their livelihoods. These results are comparable to a curriculum-based CCE conducted by Havea (2021), who found that, at the end of her study, Tongan students' secondary improved their understanding of climate and weather and gained a more scientific understanding of CC. From the findings, students indicated CC impacts of cyclones and droughts, rising sea levels, migration, and health problems.

Secondly, the findings of this study indicate improvement in pupils' understanding of greenhouse gases after CCE. About 90% of pupils stated that increased carbon dioxide is due to humans using more fossil fuels. They also indicated that global temperatures are rising because of increased carbon dioxide from fossil fuel burning. A large number of fifth and sixth-grade pupils stated that greenhouse gases that regulate the temperature and climate on Earth include carbon dioxide, methane, nitrous oxide, and water vapour. Considering these findings, the majority of pupils were able to describe greenhouse gases and their effects following the implementation of a visual innovative tool in the teaching CC. Our findings are mirrored in the experimental studies in other countries. Therefore, Niebert & Gropengiesser (2012) adopted visualising and comprehending erroneous thinking to address the misunderstanding of atmospheric carbon dioxide among 18-year-old German students. The results indicated that students valued the function of atmospheric carbon dioxide in heat retention. In addition, Havea (2021) has conducted a curriculum-based intervention in Tonga. The results reported that most students no longer associate ozone depletion with CC.

Thirdly, the study addresses the gaps that fifth and sixth grade pupils must be able to enumerate the causes of CC, indicate the impacts and mention mitigation and adaptation strategies regarding CC. Therefore, the results collected from pupils revealed that the invention was successful, considering pupils' views about CC related issues. According to the findings, more than 90.0% of pupils agreed that CC is caused by human activities, such as burning coal, natural gas and oil, cutting down trees, crops production (rice, cotton, and maize), air conditioners, and some natural causes, such as water vapour and bush or forest fires.

Regarding pupils' views about the impacts of CC, the CCE with innovative green wall and curriculum-based education, most of the fifth and sixth graders agreed with the perceptions statements included in the survey such as worsened floods and droughts, health and financial issues for people, crop and livestock production failure, migration, pollution (air and water), heat waves, forest disappearance, silting, and weed invasion for water resources.

Moreover, CC mitigation and adaptation are critical components of the intervention. Accordingly, about 90.0% of fifth and sixth-grade pupils are in agreement to the mitigation techniques included in the survey, including, waste management, protection of forest and tree plantation. These findings suggest that the multidisciplinary CCE, incorporating an innovative green wall, led to improved knowledge of CC mitigation strategies among fifth- and sixth-graders.

Furthermore, the curriculum-based approach with the innovative green wall was significant for fifth- and sixth-grade pupils to determine CC adaptation strategies such as climate smart agriculture, protect against floods, droughts and windstorms. The pupils who participated in the study agreed on awareness efforts, exhibitions, and writing opinion pieces on CC. Through practical action, the researcher provided Acajou tree seeds, and fifth and sixth-grade pupils developed the Acajou tree nursery using the old sachet of water by the beginning of the intervention. Moreover, they have taken care of them until they grew up, and we have planted those trees together in their schoolyard. These findings are consistent with those of previous studies conducted in other countries. For instance, Zografakis et al. (2008) conducted an energy education project among the student participants in Crete. Their findings indicated that the number of individuals exhibiting energy-efficient behaviour increased post-project involvement; at the same time, the percentage demonstrating energy-wasting behaviour diminished. Comparing the adoption of green walls as supplement tools in teaching and learning CC, this study mirrored studies conducted in Switzerland and Turkey, in which worksheets, simple drawings, or cartoon illustrations were implemented in small group discussions to teach knowledge about global warming; the methods were proven effective for teaching global environmental issues by increasing students' knowledge about global CC (Oluk & Ozalp, 2007; Reinfried et al.,

2012). Furthermore, our study's findings align with those of Havea (2021), who employed the cultural teaching and learning approach and method “Talanoa” to educate Tongan secondary school students and their educators on CC-related matters. The results demonstrated that participants possessed an advanced and comprehensive understanding of CC causes, effects, mitigation, and adaptation, including energy waste, cutting down trees and burning fossil fuels as causes and saving energy, saving water, walking or riding bicycles, avoiding tree cutting, and refraining from burning trash as mitigating and adapting to CC. After assessing CC knowledge, student respondents were more willing to take action addressing CC and being change agents in their schools and communities. One student mentioned that she intends to “walk to school and encourage her friends and family to do likewise”. Another stated that he “would assist in informing the people in his community to stop cutting down trees”. Most research participants said they are prepared to consume less electricity at home. This study concurs with the study that employed the innovative e-learning approach (Sanga et al., 2021), including webinars and social media campaigns, disseminating CC information to a broader audience, especially for students and young people. Furthermore, the findings are comparable to those reported by CARE International au Mali (2022), who applied a curriculum-based CCE. The study found that 57% of Malian students understood disaster risk reduction strategies such as reforestation, improved water drainage systems to prevent flooding, and adolescent-led advocacy actions. Therefore, after implementing a curriculum-based CCE among school children, the study found that 76% of the girls reported receiving information via phone regarding drought risks, 72% concerning flood risks, 42% had engaged with the project's mobile platform to enquire about CC-related events, and 40% had sought information on natural disasters. The findings of this study revealed that experimenting with innovative green walls, combined with a multidisciplinary curriculum-based education, has achieved the learning goals among fifth and sixth-grade pupils.

5. Conclusion

This study experiments with climate change education (CCE) using an innovative green wall approach among fifth- and sixth-grade pupils from primary schools. The purpose is to evaluate the impacts of green wall and curriculum-based CCE among fifth and sixth-grade pupils of Koulikoro, Mali. The study stated that by the end of the CCE, fifth- and sixth-grade pupils must be able to: define CC, cite causes of CC, determine impacts of CC, and enumerate mitigation and adaptation strategies about CC. Therefore, CCE topics were included in the subjects of five competency domains of the curriculum and adopted in this study. The green wall also presented activities related to CC issues, causes, impacts, mitigation, and adaptation. After forty (40) hours of professional development, teachers have successfully implemented the intervention among their respective classes.

According to the findings of this study, pupils revealed misconceptions about climate and weather in their current views. The results from the innovative education indicated that pupils mostly addressed the conflation between climate and weather. Although climate change is a serious problem for Mali, pupils' perceptions of CC-related issues were limited, particularly regarding the causes of CC and the adaptation and mitigation strategies to mitigate its impacts. However, the innovative green wall with curriculum-based education was impactful among fifth and sixth-grade learners. The findings indicated that the education addressed pupils' conflicting beliefs about the greenhouse effect, sunlight, and ozone layer depletion. CCE enhanced the study participants' understanding of CC causes, impacts, mitigation strategies, and adaptation measures. The innovative CCE provided an intellectual space for pupils to explore their knowledge and gaps in understanding about CC, placing them at the forefront of the teaching process to address their shortcomings. CCE was particularly important among learners due to its integration across subjects and visualisation in the classroom.

From a practical standpoint, the competency-based curriculum and the green wall also helped pupils explore broadly how CC's impacts may affect themselves, their families, society, and systems. Moreover, the curriculum-based education and green wall successfully fostered interest and developed sufficient knowledge of CC for pupils to create action plans to mitigate and adapt to CC. Despite limited time and a busy timetable, pupils significantly improved their understanding of CC, including the meaning of CC and the causes, impacts, mitigation and adaptation of CC. This research addresses the gaps in adopting a competency-based curriculum and utilising a green wall to enhance climate literacy among young learners. The research enabled pupils working in groups to freely share their ideas, express themselves from the heart, and utilise a visual tool for co-constructing ideas. It offers practical insights to guide policymakers and educators in enhancing climate education.

Curriculum-based CCE with an innovative green wall produced positive effects regarding fifth- and sixth-graders' views of CC; however, the study has limitations. The relatively small sample size, comprising fifth- and sixth-grade pupils from two primary schools in Koulikoro, cannot fully represent the broader population of primary school pupils in Mali. The experimentation was formulated and executed to coincide with the last two trimesters of

the academic year. The teaching/learning process followed the school's timetable, and lesson planning had to adhere to the duration of each period. Learning outcomes in the post-assessment of pupils was a survey questionnaire.

To address these limitations, future research could expand the sample size and include schools from various regions of Mali to obtain a more comprehensive and effective competency-based approach and a deeper understanding of pupils' views and understanding of CC. A longitudinal study with qualitative data may also better comprehend pupils' knowledge about CC.

Promoting interdisciplinary approaches that connect CCE with other subjects and foster a culture of lifelong learning will further enhance the impact of these educational initiatives. Overall, CCE in Mali is evolving through curriculum integration, community engagement, NGO support, technological advancements, and youth participation. These trends highlight a collective effort to equip the Malian population with the knowledge and skills necessary to conquer the obstacles posed by CC, ultimately contributing to a more sustainable future for the country.

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