



In-service and pre-service physics and chemistry teachers' knowledge and perceptions about renewable energies education

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Abstract

With climate change education (CCE) not included in Malian official programs of general secondary schools and physics and chemistry teachers are left to integrate it into their respective lessons. A survey was conducted to assess in-service and pre-service physics and chemistry (PC) teachers' (n = 82) knowledges and perceptions for through renewable energies (RE) education in Mali. At the in-service teacher's level, 85% desired to integrate RE, contrary to explaining climate change causes and consequences, perhaps because integration of CCE requires a didactic transposition that involves two major constraints: the legitimization of knowledge and the gap with scholarly knowledge, with compliance with programs to be satisfied first. Pre-service (master's degree in PC) teachers' results showed the influence of the disciplinary approach, with small differences and a complementarity of REs knowledge advantages and disadvantages, implying that teachers can actively participate in curricular innovation through CCE integration.

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INTRODUCTION

Climate change results from the disruption of biogeochemical cycles due to anthropogenic activities. Numerous studies have focused on Climate change education (CCE), the authors of which have relied on one or more of the 17 Sustainable Development Goals (SDGs) of UNESCO's 2030 Agenda (2021), using a pluralistic approach (complex, interdisciplinary, and systemic). CCE helps students understand and address the impacts of the climate crisis, empowering them with the knowledge, skills, values and attitudes needed to act as agents of change (UNESCO, 2021); and teachers play an essential role in formal CCE.

So, research on teacher perspectives focuses on teachers' perceptions of barriers and levers to the CCE in order to understand how to minimize and maximize them respectively. Clorion et al.'s study (2024) concerning 155 future teachers in the Philippines and Drosos et al.'s study (2022) concerning 510 school principals' perceptions in Greece on RE choices within the framework of CCE revealed that teachers and future teachers are primarily in favor of solar energy or have good knowledge of it. These results showed that priority educational choices on RE are made according to geographical situations (Stevanović et al., 2022). These geographical considerations were also perceived by 454 teachers in Greece, but not by their local communities (Liarakou et al., 2021). These teachers' beliefs in favor of RE constitute levers for CCE, but only in priority areas. However, the opinions of certain communities can

act as obstacles to CCE. Schools are privileged means for students, future societal actors, and citizens of each country.

Other surveys with in-service and pre-service teachers have focused on the risks linked to RE. However, their findings are controversial. The 642 pre-service teachers surveyed by Demirbag and Yilmaz (2020) had negative attitudes towards RE in terms of risks. Contrarily, 53% of the 412 primary school pre-service teachers surveyed by Stylos and Kotsis (2023) did not agree that bioenergy would lead to a food crisis. These controversies can be levers or obstacles depending on whether they are clarified or remain subjects of contradiction. Based on statements from 147 teachers and parents, Baker et al. (2019) suggested that more attention should be paid to satisfying the emotional needs of children on climate change. According to these authors, teacher anxiety regarding the direct and indirect impacts of climate change is an obstacle to CCE.

Teachers' professional development has also been extensively studied. Teachers' motivation is a lever that influences their teaching on climate change (McNeal, 2017). Therefore, professional development programs have been implemented on teaching methods, content, construction, and implementation of resources through teacher-training workshops on CCE. Pre- and post-test analyses have shown a positive impact on teachers and learning (Li et al., 2019). However, not confident that climate change is happening and self-confidence were obstacles for CCE mentioned by 31.37% of 54 teachers in the survey conducted by Ennes et al. (2021). These obstacles and lack of time have prevented teachers from engaging in professional development programs on climate change. Deep convictions of subject teachers who do not have CCE in school curriculum go beyond these perceptions depending of previously knowledges (Johnstone, 2000).

This research work aims to identify physics and chemistry teachers' knowledges and perceptions about REs education. CCE through REs is not part of the chemistry and physics syllabus at the level of the general secondary. The integration of CCE into chemistry and physics courses can be achieved through the conceptualisation of physics and chemistry as a curriculum requirement.

Global warming: a systemic viewpoint

The Earth has an average temperature that makes it habitable because of the natural greenhouse effect of water vapor, a critical component. Excess water vapor condenses in the atmosphere, unlike greenhouse gases such as methane (CH₄), carbon dioxide (CO₂), nitrous oxide (N₂O), and ozone (O₃). These gases are emitted during the extraction and combustion of fossil fuels and coal. Global cooling is another source of climate change (Meilinda et al., 2016). Indeed, other gases, such as chlorofluorocarbons (CFC), in the process of destroying the ozone layer, expose us to the ultraviolet radiation absorbed by the ozone layer. The destruction of the ozone layer also contributes to the cooling of the Earth. Liu and Roehrig (2017) highlight the insufficiency of teachers' justification about CC: the co-occurrence of increase in CO₂ and temperature or the percentage of CO₂, does not correlate with CO₂ levels, human activities (fossil fuels combustion) and temperature.

The resulting fluctuations of CC cause heavy precipitation or long periods of drought, ice melting and expansion of ocean water, infrastructural destruction, loss of agricultural land, massive displacement of human populations, and famine (Lamoureux & al. 2015; Trenberth, 2018). Fossil fuels also affect human health, causing waterborne diseases and respiratory problems due to tropospheric ozone, nitric oxide, and smoke. In addition, the consequences of climate change are accentuated by increases in population and energy needs. For example, a state of disaster was declared by the Malian authorities, and the 2023-2024 school year was postponed by one month as hundreds of schools were either flooded, degraded, or occupied by tens of thousands of displaced people. These displaced individuals, who had lost everything, received help from the Malian authorities and other organizations, including food, medicine, clothes, and school kits for their children. The upheavals linked to climate change have called

into question several forecasts regarding agricultural matters. Resilient plant varieties that grow in deserts have been studied and improved upon by scientific researchers to combat hunger. However, CO₂, a greenhouse gas, contributes to acid rain that destroys these plants (Atkins & Jones, 2010). Currently, the Sahel area is facing persistent monsoons and heavy rainfall, making it unsuitable for early seed varieties identified by research. These reasons, among others, explain the mobilization of public authorities and subregional, regional, and international institutions in favor of renewable energies (REs). Knowledge of these concepts protects teachers from misconceptions when teaching students about climate change disasters. It also allows teachers to raise student's awareness and make demonstration in connection with global warming. Sieg et al. (2019) used infrared camera to demonstrate CO₂ greenhouse effect by energy absorption measurement. This phenomenon, due to chemical bond (Tounkara & Soudani, 2025), is different from heat transfer by conduction and convection, and preserves physics and chemistry teachers from misconceptions (Maron et al., 2022; McCuin, 2014).

Renewable energies

REs have been defined differently concerning their less polluting nature, constant renewal from natural flows, and even their technological aspects (Hansen & Percebois, 2019; Mohtasham, 2015; Gross & Mautz, 2014; Zacchia et al., 2022). The International Renewable Energy Agency (IRENA) defines renewable energy as all forms of energy produced from renewable sources in a sustainable manner; this includes bioenergy, geothermal energy, hydropower, solar energy, wind energy, and ocean energy (tidal, wave, and ocean thermal energies). REs, such as bioenergy, hydroelectricity, and solar energy, have advantages that help minimize the causes of climate change; however, their disadvantages must also be addressed.

Bioenergy

Bioenergy is renewable energy provided by biofuels (bioethanol and biodiesel), derived from plant matter via photosynthesis. The advantage of biofuels is that the CO₂ consumed during photosynthesis equals that emitted during combustion of the biofuel. However, activities linked to biofuel production (land clearing, plantation plowing, harvesting, physicochemical pretreatments, seed oil extraction, and alcohol solution distillation) are currently powered by fossil fuels. Biodiesel, in turn, establishes competition between food (edible oil) and energy. In addition, biofuel combustion produces NO_x gases that induce the formation of tropospheric ozone, similar to that produced by fossil fuels. However, improvements are possible, such as the use of catalytic converters that transform NO_x into non-polluting dinitrogen N₂, the use of woody biomass plants (non-food plants producing cellulose), and algae that do not require agricultural land (Baird & Cann, 2016; Ximenes, 2021). Without these improvements, the quantity of CO₂ emitted would only be slightly lower than that emitted by fossil fuels.

Solar energy

The absorption of energy from solar radiation and its conversion can be done thermally by metals that capture infrared rays, mirrors that concentrate solar light on a fluid, or by photoconversion, where photons from solar radiation are absorbed by photovoltaic (PV) materials (Baird & Cann, 2016; Stevanović et al., 2022). Solar energy has advantages, such as the possibility of domestic installation, which avoids costly transport of energy, and low CO₂ emissions during equipment manufacturing. However, solar energy also has disadvantages, namely its intermittent nature and the production of direct current, which require storage and transformation of energy during its use; large installations due to low energy conversions (20%) by PV cells; and battery recycling (Peters et al. 2021; Stevanović et al., 2022). Prospects for improvement exist, such as research on dye-based solar cells, which may increase the conversion rate of solar energy.

Hydroelectric power

Hydroelectric energy is the energy transmitted to a turbine (located at the bottom of a dam) by falling water. This potential energy is proportional to the product of the water volume (mass in physics) and height of the waterfall. It is by far the most important renewable energy source. Hydroelectric dams have several advantages in addition to supplying electricity, such as agricultural irrigation and improving river navigability (Ficatier & Niasse, 2008; Vaucelle, 2015). However, the environmental and economic costs, as well as the sociocultural consequences, are enormous. These include displacement of human populations (sources of conflict); disappearance of fish due to reduced mobility between downstream and upstream of the dam; flood risks; high-voltage transmission line impact; greenhouse gas emissions (CH₄ and CO₂); eutrophication and silt accumulation in water reservoirs; seasonal fluctuations; and the emergence of water-borne diseases (Baird & Cann, 2016; Ficatier & Niasse, 2008; Hanna et al., 2016; Furtado Louzada & Ravena, 2019; Vaucelle, 2015).

If the disadvantages do not call into question the nature of clean energy, it would still be necessary to understand them and their impact. Schools are the preferred means of achieving the cognitive, socio-emotional, and behavioural learning objectives regarding clean energies within the framework of CCE. Learning involves the use of innovative teaching methods. Teachers, who are the main actors, must adhere and contribute to this effort, hence the need for assessing their perspectives.

Specific questions and hypotheses

What are in-services teachers' and pre-service teachers' knowledges about REs advantages and disadvantages and its integration in chemistry and physics courses? How do PSTs view the use of REs? We hypothesized that: relationship between physics and chemistry teachers' knowledges can be considered as complementary, which predisposes teachers to collaborate for curricular innovation and resource development during the integration of CCE. In addition REs have advantages and disadvantages on CC.

METHOD

The survey was conducted in October 2024 in Malian country. We used the snowball method (Biernacki & Waldorf, 1981) for in-service (n = 17) and pre-service teachers (n = 65) with master's degrees in M1 physics (n = 11), M1 chemistry (n = 12), M2 physics (n = 21), and M2 chemistry (n = 21). Although locating teachers is generally not difficult, we encountered challenges during our study period due to the state of disaster (flooding, destruction of infrastructure, displacement of residents) decreed by the authorities and the postponement of the start of the new school and university year. Questionnaires (closed questions), instruments for data collection (Tables 1, 2, 3), were sent as electronic messages to one in-service teacher and to a representative of each section, namely M1 chemistry, M1 physics, M2 chemistry, and M2 physics. Qualitative and quantitative methods are used for data analysis.

FINDINGS AND DISCUSSION

In-service physics/chemistry teachers' perceptions of CCE

The results obtained from in-service physics/chemistry teachers on Q4 and Q5 varied, from 14.81% and 85%, respectively. The results for Q5 show that teachers supported the introduction of climate change topics in physics/chemistry courses, which is not yet included in Malian national programs. They expressed a preference for addressing anxiety (Q2-33.33%) over explanation (Q4-14.81%), despite explanation and prediction being the essential functions of the model, and physics and chemistry considered as modeling sciences.

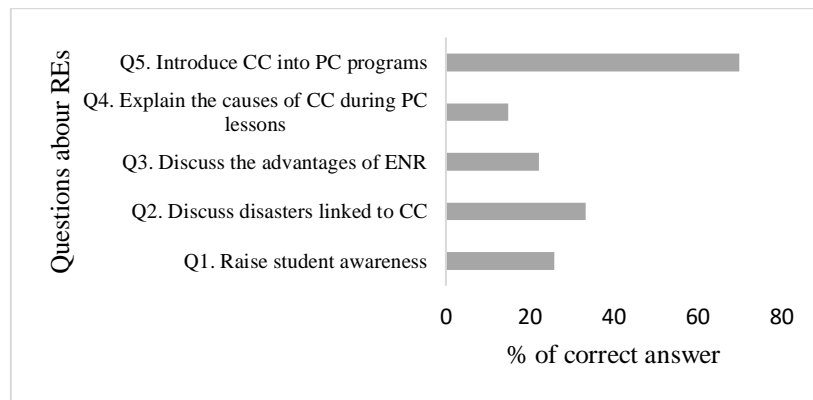


Figure 1. In-service teachers' view about REs.

Pre-service teachers' beliefs about REs in CCE

All results obtained from pre-service teachers—M1C, M1P, M2C, and M2P—regarding the advantages (A1-18) and disadvantages (D1-18) of RE, as well as its possible integration into physics courses, are presented in Tables 1-3.

Solar energy

The results for solar energy showed that pre-service teachers in M1C presented the highest percentages on aspects directly related to climate change, whereas M1P (PSTs) registered the highest percentages for technological aspects (Table 1). However, the highest percentages in M1C compared with M1P for A5 and A6 (Table 1) regarding integration were unexpected. This may be because they have fewer physics units than M1P and therefore less to learn. Regarding pre-service teachers in M2C and M2P, the results showed that those in M2P recorded the highest percentages, except for A1 (M2P-42.86%/M2C-80.95%), D4 (M2P-85.71%/M2C-95.34%), and D5 (85.71/90.48). Production by capturing infrared rays using a metal (A1), for example, is a matter of general knowledge. However, for D4 and D5, M2P (PSTs) favored technological aspects, such as incorporating necessary devices into domestic settings. Contrarily, M2C (PSTs) favored the fundamental aspects, such as the storage of electrical energy as chemical energy (batteries) and its transformation back to electrical energy during use.

Table 1. Pre-service teachers' view about solar energy (M1 and M2 levels)

Advantages (A) and disadvantages (D) of solar energy	Percentage (%) of agree			
	M1C	M1P	M2P	M2C
A1. Production by capture of infrared (by a metal)	41.67	63.64	42.86	80.95
A2. Production by mirrors (concentrate on fluid)	66.67	72.73	66.67	42.86
A3. Production by photoconversion (PV)	100	72.73	100	90.48
A4. Possibility of domestic installation	100	72.73	90.48	80.95
A5. Can be integrated into the photoelectric lesson	75.00	81.81	90.48	76.19
A6. Can be integrated into the electronics lesson	83.33	54.55	85.71	76.19
D1. Low energy conversion rate	66.67	81.81	100	80.95
D2. Requires large surfaces for large productions	66.67	81.81	100	71.43
D3. Electricity production linked to sunshine	66.67	90.91	90.48	57.14
D4. Requires energy transformation	66.67	63.64	85.71	95.24
D5. Production of direct current	75.00	90.91	85.71	90.48
D6. Production of carbon dioxide (manufacture)	83.33	72.73	85.71	66.67

Hydroelectric power

The results for hydroelectric power showed small differences between M1C and M1P; and between M2C and M2P (PSTs) (Table 2), with results favoring PSTs (M1C and M2P). However, for M2C and M2P (PSTs), gaps existed in A7 and D7, where A7 and A11 related to physics and D7 to chemistry, directly linking to climate change through greenhouse effects.

Table 2. Pre-service teachers' perceptions about solar energy and hydroelectric power (M1 and M2 levels)

Advantages and disadvantages of hydroelectric power	Percentage (%) of agree			
	M1C	M1P	M2P	M2C
A7. Production of alternating current	100	72.73	100	85.71
A8 Important than solar energy and wind turbines	75.00	100	85.71	71.43
A9. Charging electric vehicles (ecological)	91.67	63.64	85.71	80.95
A10. Water can be stored or released as needed	100	100	76.19	90.48
A11. Can be integrated into the course on potential energy	83.33	63.64	85.71	76.19
A12. Can be integrated into the course vapor pressure	75.00	63.64	85.71	76.19
D7. Production of greenhouse gases (CH ₄ and CO ₂)	83.33	54.55	76.19	95.24
D8. Hindering fish populations mobility	91.67	90.91	90.48	95.24
D9. Human populations shift upstream (conflicts)	91.67	100	85.71	80.95
D10. Scarcity of water downstream (conflicts)	66.67	100	66.67	61.90
D11. Negative impact of high voltage lines	83.33	81.82	85.71	80.95
D12. Can cause disasters (floods, waterborne infections)	100	81.82	90.48	90.48

Bioenergy

The results for bioenergy showed a small difference between PSTs (M1C and M1P), with M1C favoring statements directly linked to global warming (A16, A18, and D13) compared to M1P (PSTs) (Table 3). The M2P (PSTs) scored above 70% across categories, except for A16, A17, and D14 (related to chemical aspects) and D15 (related to general knowledge). For M2C (PSTs), all categories were above 80%, except for D14 and D15. The percentage of alcohol in the alcoholic solution (11%) was not specified in statement D14, which may have contributed to a lower score.

Table 3. Pre-service teachers' perceptions about bioenergy (M1 and M2 levels)

Advantages and disadvantages of bioenergy	Percentage (%) of agree			
	M1C	M1P	M2P	M2C
A13. All CO ₂ from combustion is consumed by photosynthesis	66.67	90.91	76.19	80.95
A14. Possible production from woody biomass crops (cellulose)	100	81.82	100	85.71
A15. Possible production from algae with wastewater	91.67	90.91	85.71	90.48
A16. Catalytic converters transform NO _x into N ₂ (non-polluting)	91.67	72.73	66.67	90,48
A17. Can be integrated into liquid-liquid distillation courses	66.67	90.91	66.67	80.95
A18. Can be integrated into the lesson on carbon cycle	100	72.73	85.71	85.71
D13. CO ₂ and NO _x induce the formation of tropospheric ozone	100	63.64	90.48	80.95
D14. Requires large amounts of water for production	66.67	63.64	66.67	71.43
D15. Competition for food against biofuels	66.67	81.82	57.14	61.90
D16. Necessary clearing of large areas of land	91.67	81.82	85.71	85.71
D17. Causes land erosion	75.00	72.73	100	80.95
D18. Low yield for bioethanol	100	72.73	90.48	90.47

All results on solar energy, hydroelectric power, and bioenergy integration in physical and chemical science courses (A5, A6, A11, A12, A17, and A18) show that respondents adhered to CCE through RE.

Constraints and teachers' adhesion for CCE

Results obtained from in-service teachers for Q4 (14.81%, the lowest) and Q5 (85%, the highest) appear contradictory. Introducing climate change into physics and chemistry courses requires didactic transposition, which presents two major constraints: the legitimization of knowledge and the gap with scholarly knowledge (Chevallard, 1999). The teachers surveyed seemed to consider the first constraint as climate change not being in the Malian official program of physics and chemistry, same to environment education (Tounkara & Soudani, 2022). The second constraint can only be addressed by teachers when CCE integration is required in the curriculum. Therefore, the teachers desired the inclusion of climate change topics in the programs (Q5/85%). This perspective can also be explained by a disciplinary approach. Yli-Panula et al. (2023) found that more than half of the 113 student teachers of biology and geography were interested in sustainable development (SD), confirming that interest in SD varies with the discipline. The mention of disasters did not record the lowest rate because the entire central and western Sahel (Chad, Niger, Mali, Burkina Faso, Mauritania, and Senegal) faced unprecedented flooding in 2024.

Pre-services teachers' interdisciplinarity knowledge about CCE

The results from PSTs (M1C and M1P) showed a high percentage of physical, chemical, biological, socioeconomic, and cultural aspects linked to climate change, indicating that pre-service teachers were prepared for the transversality of CCE through RE. M1C and M1P favored all three types of RE, an approach recommended by Akorede et al. (2017), who suggested that countries could address the energy crisis by exploring abundant renewable energy resources rather than relying on a single energy source.

PSTs (M2P and M2C students) knew of the advantages and disadvantages of solar energy and were in favor of it, with 79.37% and 74.60%, respectively. The geographical situations of the countries that may lead to the lack of fossil fuels have also influenced their embracing of solar energy (Clorion et al., 2024; Drosos et al., 2022; Liarakou et al., 2021; Stevanović et al., 2022). Solar power is the only short-term alternative to such countries' energy crisis. Teachers will, therefore, have to draw students' attention to the exhaustible nature of fossil fuels, in addition to highlighting the disadvantages that need to be minimized. Laboratory work integrating Solar cells integrated in photoelectric effect courses (grade 12) allows teachers to break away from the classic protocol-based model; causes of students' performance and conceptual change about of energy transformation (Kishore & Kisiel, 2013).

Regarding hydroelectricity, the particularity of hydroelectric dams is that they are one of the causes of climate change (production of CH₄ and CO₂) and can lead to floods, destruction of infrastructure, water-related diseases, and impacts on biodiversity. Greenhouse gas emissions have been higher than those of fossil fuels producing the same quantity of energy for several years. Knowledge of its advantages and disadvantages, as well as favorable geographical situations (waterfalls), is necessary for CCE. PSTs, M2P and M2C students, know the advantages and disadvantages linked to hydroelectric dams and are favorable to teaching and learning on this basis at 84.52% and 82.14%, respectively. The respondents affirmed that hydroelectric energy could be integrated into the course on potential energy (76.19% for M2C and 85.71% for M2P). Genç and Akilli (2019) arrived at the same results. They surveyed 1,145 teachers in initial RE training. The results of the descriptive statistical analysis showed a strong correlation between the respondents' knowledge of and positive attitudes towards RE. However, in the work of Guven and Sulun (2017), 54% of the 196 pre-service teachers surveyed did not consider hydroelectric energy as a potential RE. Because this misconception, they did not have a positive attitude

towards RE by extension CCE. The results for hydroelectricity and solar energy are not 100% either. This is explained by the specificity of the statements. According to Johnstone's theory on the information processing process (2000), some statements are ignored depending on the specialty (physics or chemistry) of the PSTs.

Regarding bioenergy, advantages and disadvantages of biofuels were considered contingencies. All the CO₂ produced during the combustion of biofuels may or may not be consumed during photosynthesis, depending on whether the energy necessary for its production activities comes from biofuels or fossil fuels (A1). Halder's (2016) found similar results to our findings (D2: 57.14% agree for M2P and 61.90% agree for M2C) regarding edible oil competition with biodiesel. In order to minimize the inconvenience, the use of large quantities of water (D2) can be reduced or replaced by wastewater during the cultivation of algae (D3) and food plants by woody plants. Having all been trained in environmental chemistry or physics, the results relating to the adherence of PSTs to the advantages and disadvantages of bioenergy are not 100%. This is due to the transversality of bioenergy (including physics, chemistry and biology); but especially to the possibility of the assertions. It is a misconception to declare no relationship between hydroelectric dams and greenhouse effect or biodiversity. Indeed, we have demonstrated in the theoretical part that bioenergy is only ecologically profitable in a cyclical process. The carbon dioxide produced must be incorporated into the photosynthesis process as stipulated by the concept of the atomic economy. However, despite these eventualities, M2P and M2C teachers knew the advantages and disadvantages linked to bioenergy, at 80.95% and 82.14%, respectively. Halder (2016) obtained similar results from a survey of 50 science teachers in Finland and India. The results showed that 80% of the respondents had a positive attitude towards bioenergy and its contribution to replacing fossil fuels responsible for climate change. Our results also showed that the respondents supported the integration of bioenergy into chemistry (66.67% for M2P and 85.72% for M2C).

Possible collaboration between in-service teachers

In sum, all our findings show that PSTs (M1C, M1P, MC2 and MP2) are neither in an inclusion nor an exclusion relationship, but in a complementary physics and chemistry relationship with very small differences. Therefore, physics and chemistry teachers' collaboration will serve as a catalyst to inclusion of CCE content.

CONCLUSION AND SUGGESTIONS

This study made it possible to access in-service and pre-service teachers' perceptions of CCE during a period when the Sahel area was confronted with the consequences of climate change. The results validated our hypothesis, according to which the perceptions of the teachers surveyed were complementary. The small differences are due to the fact that these teachers are in charge of physics and chemistry at the level of general secondary schools and at the level of Teacher Training Institutes named "Instituts de formation des Maîtres (IFM)". Without integrating CCE into official programs, as desired by in-service teachers, the only alternative is to integrate climate change questions into physics and chemistry courses.

The survey did not consider global cooling. Unlike, the melting of ice and expansion of the volume of ocean water; water vapor tension allowing its condensation, and the nature of the chemical bonds of molecules explaining the greenhouse effect also remain implicit in the investigation, with samples limitation. These results have significant implications for the educational system for CCE implementation. Indeed, respondents who had been trained in environmental chemistry and physics can be associated with curricular innovations in CCE. This approach is opposed to one that consists of curricular innovation before training teachers. From this perspective, project plan is to study classroom

practices on this integration and make proposals on pedagogical and didactic approaches to CCE in initial and subsequent teacher training.

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