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Climate Changes: Fact or Fake? Low-Cost Hands-On Experiments to Verify It

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Abstract

Climate changes (CC) remain a polemic topic, often causing conflicts. Scientific data indicate that the average planet temperature is rising mainly for anthropogenic actions, but this understanding must be widespread to influence the public opinion on attitudes and policymaking. Since our brains did not evolve to respond to slow/complex threats, as CC, we designed rapid, simple, interactive, hands-on educative activities. Inexpensive/reused material was employed to demonstrate the atmospheric alterations effects on global warming. We used plastic cake boxes with analogical thermometers or digital thermohygrometers and CO_2 release by effervescent tablets to mimic the greenhouse effect. The system demonstrates the influence of CO_2, water vapor, smoke, weather, etc. on the air temperature and humidity. CO_2 enhanced temperatures within the boxes, by up to 6˚C. Interestingly, in the presence of vegetation, increased temperatures were associated with decreased air humidity and simultaneous water condensation on the box cover, apparently indicating increased evaporation and water drop formation. Educators of different disciplines (Earth Science, Biology, Physics, Chemistry, Environmental Education, Ecology, etc.) and students can perform simple, transdisciplinary, hands-on activities within 50 min, evaluating different factors on the air temperature, and promoting transdisciplinary discussions during classes. In addition, the public can rapidly grasp CC principles in science fairs, promoting science literacy.

Keywords

Climate Changes, Environmental Education, Hands-On Activity, Global Warming, Experimental Learning

1. Introduction

Climate changes (CC) are presently widely accepted in view of robust evidence. According to the US National Oceanic and Atmospheric Administration, January 2020 was the hottest on record, 2019 was the second warmest year and most of the warmest years were recorded in the second half of this decade (NOAA, 2020). These enhanced temperatures are implicated in the speedup of Greenland ice sheet melting (King et al., 2020).

CC can affect biodiversity (Sala et al., 2000), public health (Hashim & Hashim, 2016; Kovats & Haines, 1995; McMichael et al., 2003; McMichael et al., 2006; Mills, 2009; Patz et al., 2000), human conflicts (Lee, 2009; Mach et al., 2019), agronomic production (Brouder & Volenec, 2008; Huntingford et al., 2005), tourism (Becken & Hay, 2007; Shurland & Jong, 2008), energy production (Steyn et al., 2014; Richter, 2010), transportation (Lucas & Pangbourne, 2012; Grammelis, 2016), fishery (Phillips & Pérez-Ramírez, 2018), etc. CC may enhance the severity and damaging potential of tropical cyclones, hurricanes, droughts, wildfires, floods, etc. (Kossin et al., 2020; Mudd et al., 2014; Sauerborn & Ebi, 2012; Walter, 2017), including deadly storms such as the 2017 Atlantic hurricane season, particularly marked by hurricanes Harvey, Irma, Jose and Maria. Recent predictions indicate, besides increasing hurricane activity, the above-normal levels in the 2022 season (Klotzbach & Bell, 2022). These events apparently follow a pattern that includes devastating floods in USA, China, Indonesia and Pakistan, unprecedented heatwaves and fires in Russia and Australia, catastrophic mudslides in USA, Swiss Alps and Brazil, tropical cyclones striking Pacific Islands, causing innumerous victims and remarkable economic losses.

For different reasons, CC may cause 250,000 additional deaths every year (WHO, 2021). In two decades over half a million people deceased due to extreme weather worldwide (World Economic Forum, 2019) and in nearly four decades extreme climatic events, including tropical cyclones resulted in 13,188 deaths solely in the US. Hurricanes Katrina and Harvey caused at least 1833 and 88 deaths, respectively (NOAA, 2020). Recently the heatwave struck Europe, the World's 1st to be named (i.e. Zoe), caused 40.3˚C (757.4 ˚F) in UK, 45˚C (113 ˚F) in Spain, 47.0˚C (116.6 ˚F) in Portugal and over 1000 deaths in Spain and Portugal (Kirby, 2022). The heatwave that struck Karachi, Pakistan, with temperatures reaching 45˚C (113 ˚F) was reported to have caused 860 deaths. The passage of cyclone Idai by Mozambique, Malawi and Zimbabwe killed over 760 people, but the number of deaths may exceed 1000 as hundreds were missing. Heatwaves in 2018 caused about 74 deaths in Quebec, Canada and 80 in Japan, besides numerous hospitalizations. Fatalities are particularly frequent in nations with limited resources such as Myanmar. Recently hurricane Laura with winds of up to 240 km/h (150 mph) caused a death toll of over 30 people in Haiti, 14 in the US and 6, in Dominican Republic. In the US this hurricane caused chemical fire from an industrial plant and the coastal areas of Louisiana recorded 400,000 people without power and 200,000 without water (Rising et al., 2022).

Besides inestimable suffering and death-toll, hurricanes, droughts, storms, etc.

cause costs on properties lost and loss of productivity that may approach U$ trillions (Mechler et al., 2019), and losses of at least 1670.5 billion dollars from 1980 to 2018 in the US (NOAA, 2020). In the period 1998-2017, about $3.47 trillion was lost (World Economic Forum, 2019). Estimates for the financial losses of the 2017 hurricane season can reach U$385 billion. In the US alone extreme events such as drought, wildfires, flooding, freezes and storms are estimated to have caused average losses of $4.3 bn. per event (NOAA, 2020). Hurricanes Katrina and Harvey caused losses reaching $125 bn. (2005 USD) and exceeding $125 bn, respectively. Hurricanes Maria and Irma had total damages of $90 and $50 bn., respectively. The western US wildfires caused damages tallying $18 bn. and the climate disasters in 2017 cost U$306 bn (Shepherd, 2018). In fact, the comprehensive CC-driven economic losses may be even higher (BBC News, 2020). Such disasters may be related to CC (McGrath, 2019) and anthropogenic influence on extreme weather events is now widely accepted (Kossin et al., 2020; Santer et al., 2019; McGrath, 2019; National Academies of Sciences Engineering and Medicine, 2016).

Global warming deniers (Spencer, 2010) may be based on political positions (Hart et al., 2015; Hackett, 2016; Plutzer et al., 2016), rather than on scientific data *per se*. Most of the adult population gets information about CC through the media, presumably with insufficient scientific background (Hackett, 2016; Plutzer et al., 2016). The people trust in CC scientific data depends largely on the interest in learning science (Motta, 2018) and the trust may be promoted by environmental education (Ardoin et al., 2017), but the latter largely fails in developing pro-environment attitudes (Saylan & Blumstein, 2011) and the science teaching is often not motivating (Brophy, 2010; Macklem, 2015). In this regard, active engagement in specific project tasks can be instrumental in student motivation (Deci et al., 1999).

Because of all that, CC comprises great concern not only for scientists (Mechler et al., 2019), but also for the general population (Mann & Kump, 2015). Nevertheless, surprisingly several authors and policymakers still disregard or disbelieve global warming (Fretwell, 2007; Friel & Lovejoy, 2010; Spencer, 2010). Besides the remaining CC deniers, there are the ones that believe that such changes exist, but are not human-driven, although over 95% of climate scientists say the opposite (Cook et al., 2013) and statistical analyses demonstrate the anthropogenic fingerprint in the CC reaches the 5σ threshold, existing only one in 3.5 million chance that such changes have a different origin (Santer et al., 2019). Although numerous authors acknowledge the role of carbon dioxide (CO_2) on global warming and climate changes and carbon sequestration/storage have been widely employed for environmental mitigation (National Research Council, 2015; Ussiri & Lal, 2017) the role of CO_2 on CC remains a theme of debate (Easterbrook, 2016; Berry, 2020; Fleming, 2020; Singer et al., 2021). According to the Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC, 2022) where over 200 scientists reviewed over 14,000 studies, the unequivocal and global anthropogenic environmental changes are rapid and mainly due to CO_2 production in the fossil fuels burning.

CC affects education in different ways from health and wellbeing in the classroom (Salthammer et al., 2016) to the absenteeism among famished children due to weather effects on the crops, as shown in African nations (Dercon & Porter, 2014; Jensen, 2000) and impoverishing the low-income populations (Hallegatte et al., 2016). Some scientists made considerable efforts to spread knowledge to the general population in a form of CC science communication. Nevertheless, not all of them succeed properly. Population denialism may result in hampered CC science teaching (Reardon, 2011) and the misunderstanding of scientific data, even by politicians may hinder mitigating responses. A nationwide search carried out in the US revealed that teacher training on CC is often deficient and influenced by political and religious backgrounds (Berbeco et al., 2017). A 2018 School sustainability survey carried out by Students Organising for Sustainability National Union of Students in partnership with Green Schools Project approaching 2990 British students indicate that 86% agree that all schools and colleges should be doing things to help the environment and 85% agree that these institutions should encourage student participation. In addition, a YouGov survey (2019) commissioned by Oxfam revealed that over two-thirds of teachers believe CC should be more focused at UK schools, whereas three-quarters do not feel they were adequately trained on the topic. Around 70% agreed that radical changes are required to adapt the education system "for the times we live in". Therefore, many students declare the school's failure in CC (Burns, 2020), as the topic is approached in a fragmented and frequently superficial manner in textbooks, particularly used to inform the teacher. Furthermore, the emphasis on CC in universities programmes is limited at present (Molthan-Hill et al., 2019). Thus, the development of effective education tools is urgently required, and some are freely available online, including NASA resources (Common Sense Education, 2020). Unfortunately, many teachers declare that students tend to get attached to misconceptions such as the ozone hole causing global warming and that the CC can cause only local effects, etc. (Aubrecht, 2018; Pascua & Chang, 2015) and such misconceptions may be subject to false consensus effects (Leviston et al., 2013). Oversby stated that CC education should employ novel methods of teaching and suggested some types of innovative pedagogy, which were however restricted to questioning discussions and games (Oversby, 2015). Gaming (Carreira et al., 2017; Harker-Schuch et al., 2020), computer models (Jacobson et al., 2017), and *in silico* simulations have been employed as tools for CC education and experience gaining in dynamic computer simulations show reduced misconceptions (Dutt & Gonzalez, 2012; Qudrat-Ullah & Kayal, 2018). In fact, digital simulations and laboratory activities may be complementary in education (Ünlü & Dökme, 2015). Nevertheless, neutralizing CC misinformation and fallacies in times of fast fake news spreading via social media, demands effective and comprehensive education strategies (Cook, 2019; Armstrong et al., 2018). Hands-on activities were previously suggested (Kellner, 2017), but these are scarcely found in the literature (National Research Council, 2011; Walker &

Wood, 2009).

As climate changes may affect human health (WHO, 2021), including infectious disease vectors, health education enterprises are required, mainly in endemic areas (Araujo-Jorge et al., 2021; Suarez-Fontes et al., 2021). Therefore, education and communication interventions are of pivotal relevance for promoting climate literacy. Here our purpose was to develop a simple hands-on educational tool for demonstrating the role of CO_2, smoke and vegetation in air temperature and humidity, suitable for non-formal learning in schools, science fairs, etc.

2. Methodology

The present activity was first tried with biological science students at Rio Grande Federal University (Universidade Federal do Rio Grande), Southern Brazil by the Leopoldo de Meis National Education and Science Network (RNEC, 2022) (LMESN—Rede Nacional Leopoldo de Meis de Educação e Ciência, RNEC). This association, since 1985, gathers 39 teams of Brazilian scientists, at 23 higher education institutions (universities and Oswaldo Cruz Foundation—Fiocruz) in 11 of the 26 Brazilian estates.

In the courses offered by the LMESN, teachers and students are encouraged to pose questions, which motivates experimental designs. The topic was chosen because of the concern about ozone layer hole and global warming, among other CC. We do not offer a material list or a written procedure as the experimental design and the search for unexpensive easily available material are part of the activity. Creativity should be the main resource and both teachers and students must be empowered to use it. Curiously, it is often harder to stimulate the teacher's creativity, presumably as a side effect of inflexible formal education, usual in Brazil, where Creative Education may be declining (Jesus et al., 2019). So, we decided to simulate global warming using transparent plastic cake boxes in **Figure 1**. The box cover was carefully perforated for the insertion of a simple analogic glass thermometer. Another identical thermometer was placed besides the box held at approximately the same height and inserted in a card box piece. Digital thermometers may be used and make multiple/continuous measurements more rapid and accurate. Digital thermohygrometers also allow continuous humidity measurements, permitting kinetic analysis of variations under distinct conditions, *e.g.* simulating environmental changes. At this point, the effects of sunrays energy loss by crossing the plastic layer and being reflected by the box's secluded air and bottom may be compared to the atmosphere role. The presence of water in the cake box may simulate the atmosphere humidity in the experiment and water vapor is an important greenhouse gas. As greenhouse gases such as CO_2 are displaying increasing concentration in the atmosphere (NAS, 1997), in the present activity the presence of greenhouse gases was mimicked by CO_2 release by antacid effervescent tablets (expired medicines may also be used in the experiment).

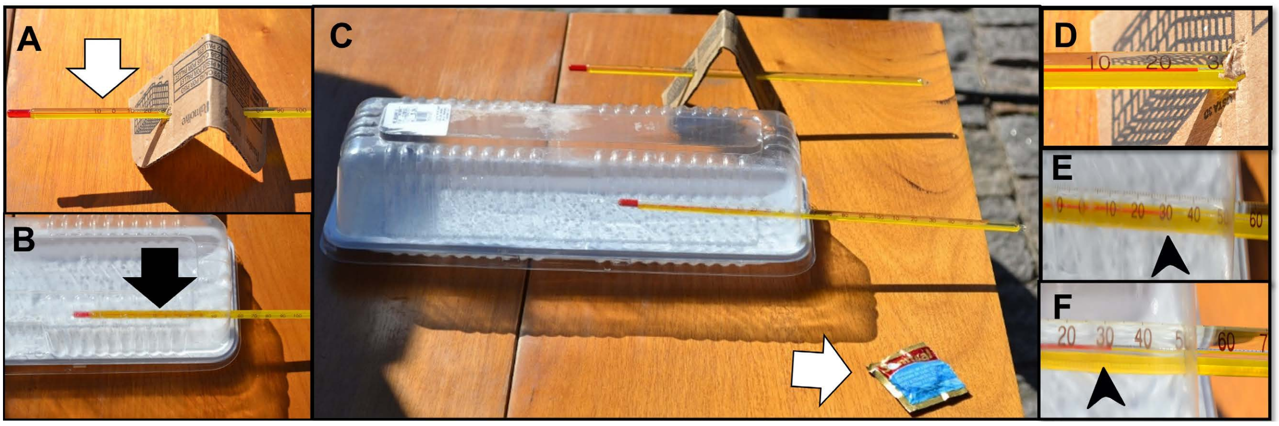

Figure 1. In an experiment performed in Southern Brazil (Rio Grande, RS, Latitude: −32˚02'06", Longitude: −52˚05'55") two identical analogic thermometers were placed on a wooden table positioned at approximately the same height, i.e. *circa* 2.5 cm from the table surface. The first was placed on a piece of folded cardboard (A, white arrow), whereas the other was carefully inserted on a transparent plastic cake box (B, black arrow) and the temperatures were determined simultaneously with or without addition of effervescent antacid tablets that release CO_2 (C, arrow). The thermometer placed on the cardboard (open/free air) recorded environmental temperature at about 25˚C (77 ˚F; D), whereas the one on the cake box showed 30˚C - 31˚C (86 - 87.8 ˚F; E, arrowhead) and 1˚C - 2˚C higher temperatures whenever the effervescent tablet was added (F, arrowhead).

The effects of pollution on the atmosphere can be simulated by the smoke produced by an ordinary (recently extinguished) cigarette. Effects of other conditions such as time of the day, locality shaded, cloudy or sunny days, the presence of plants etc. may be discussed and planned. Under different conditions, distinct model boxes were tested. In order to test the participation of vegetation cover, humus-rich earth was added to disposable cake boxes (38.5 × 28 × 10 cm) and seeds of golden birdseeds (*Phalaris canariensis*) were planted and watered daily for 30 - 35 days before the experiments. Two spaces at the middle of each half of the box length were left where disposable cups were placed with water for adding or not of effervescent tablets that release CO_2 within the tightly closed packages. Thermohygrometers fixed in a lateral hole in each package, were used to measure the temperature and humidity at different times and one was suspended in the air (a few centimeters from the floor to prevent/minimize heat conduction/convection) for environmental measurements. Open (cover top cut off) and closed (intact cover) packages were exposed to direct sunlight in the presence or absence of CO_2 released by effervescent tablets. The experiments were performed on the balcony of an apartment (during the SARS-CoV2 pandemic) in Niterói, Rio de Janeiro as well as at Universities and Fiocruz Campi on both sunny and cloudy days.

3. Results

3.1. Testing Global Warming

We employed plastic cake boxes to simulate the atmosphere interaction with the sunlight, with the retention of reflected long-wave radiation. Initially, we used analogical thermometers as they are often available in schools at developing nations such as Brazil and it is important that such activities may be performed in the school setting to be widely and perennially used (**Figure 1**).

The students were surprised that reused and inexpensive material could be employed in a dynamic and motivating activity and in less than 60 min., when the temperature within the box containing CO_2 (released by the antacid tablet) was increased, so took notes and many pictures (**Figure 2**).

Afterwards we used round cake boxes and digital thermometers (**Figure 3**), mostly in itinerant activities, as the more rapid temperature assessment at greater distances is suitable for science fairs and exhibitions (**Figure 4**).

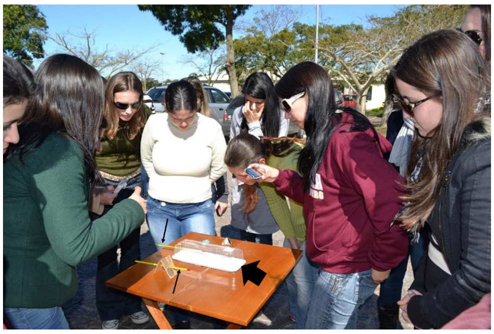

Figure 2. Undergraduate Biological Sciences students or pre-service teachers, performing global warming experiment, using analogic thermometers (thin arrows) and a cake box (thick arrow) and often documenting the activity photographically, while making excited comments and some intend to use the activity with future students.

Figure 3. Similar experiments were performed in Salvador, BA (Latitude: −12˚58'16", Longitude: −38˚30'39"), using larger, round cake boxes and digital thermohygrometers with probes inserted in the boxes (thin arrows). The system allowed kinetic measurements simpler and more precise. It may be observed that the box devoid of effervescent tablet (middle) registered 36.4˚C (97.5 ˚F), whereas the box that received the tablet (left) displayed 38.7˚C (101.6 ˚F). Another box with removed cover top (thick arrow), as a control (right), presented 35.5˚C (95.9 ˚F).

Figure 4. The climate change activity with digital thermohygrometers is effectively used in science fairs or exhibitions in public places, accessed simultaneously by numerous people.

3.2. Global Warming *vs* Pollution

In a LMESN course attended by Biology pre-service teachers, the participants asked whether plants or soil properties could affect temperatures in the system and sometimes we include plants and sand in the boxes. It is important that the students feel free to search for their own answers not getting preconceived ones. Therefore, the activity is instrumental for discussing experimental limitations such as the fact that a lit cigarette would generate heat via its burning ashes (the lit portion may reach over 400˚C, i.e. 752 ˚F, but its effects are only detected at short distances), particularly if it is placed near the thermometer sensor (**Figure 5**).

The cigarette may also carbonize the plastic surface, so interfering with transparency and sun light transmission. One could say for instance to insert the lit cigarette in the factory model in a glass or metal dish to avoid accidents and minimize carbonization and heat diffusion. Thus, the students and teachers per se may be challenged for finding solutions and be pleased to learn that scientists frequently face such technical difficulties. The students are, then, stimulated to design new experiments circumventing such inconveniencies.

The continuous temperature measurement allowed students to approach its dynamic behavior, so they decided to evaluate its kinetics under different conditions, including cloudy moments and tree shadows (**Figure 6**). Using their experiment notes, they were able to plot graphics displaying temperature changes over time (**Figure 7**).

3.3. Global Warming and Vegetation

The participation of vegetation (**Figure 8**) in kinetics of temperature and humidity change (**Figure 9**) was analyzed in order to elucidate its short-term dynamics and how it affects the weather. The periods were measured in minutes, during a class, but experiments may be designed to last longer. Kinetic measurements can be performed, and the relative roles of CO_2, vapor and temperature changes may be discussed.

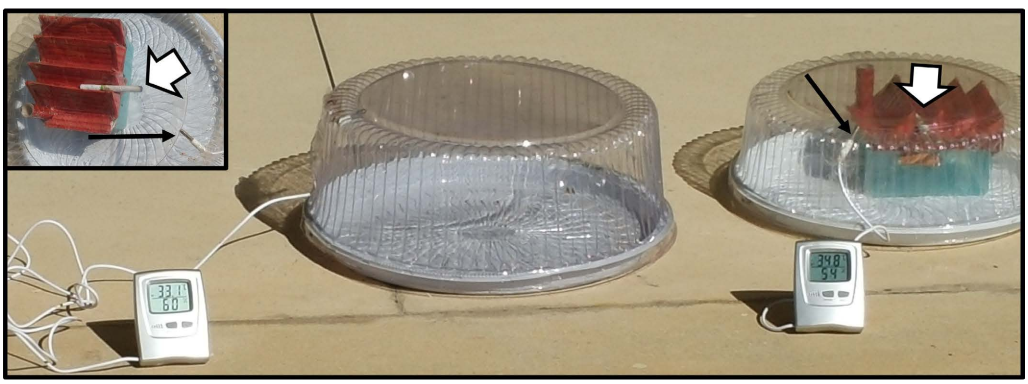

Figure 5. In experiments carried out in Teixeira de Freitas, BA, Northeastern Brazil, (Latitude: −17˚32'06", Longitude: −39˚44'31") some cake boxes were tested with lit or recently extinguished cigarettes (thick arrow). Inset shows box top view cigarette (thick arrow) on a factory model and the thermohygrometer sensor can be observed (thin arrow).

Figure 6. Science teachers in performing global warming kinetic experiments, taking notes, using mobile phones for pictures and chronometry (left inset), and comparing the temperature variations under sunny conditions or under clouds or trees-produced shades (right inset).

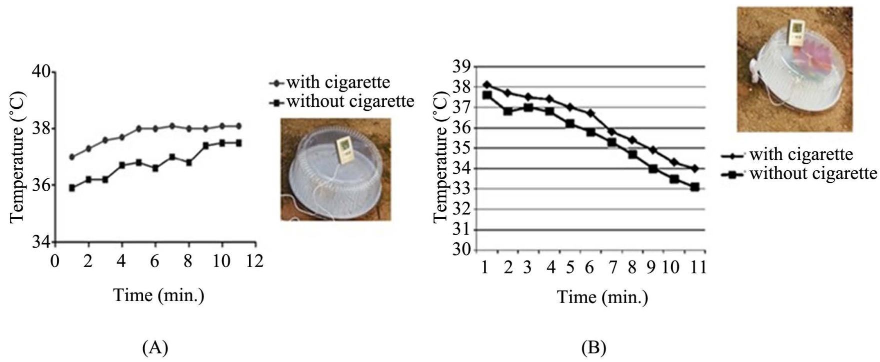

Figure 7. Temperature variation determined every minute with and without lit and recently extinguished cigarette within the cake box, under sunny (A) and shaded (B) conditions.

4. Discussion

At least 60% of the world's population is aware of the CC, but such understanding is often only weakly linked to the attitudes that minimize environmental impacts. Most of the populations tend not to take action because the human brain apparently is not well-equipped to deal with the slow and complex CC (Casper, 2010). The human mind relies on a slow/analytical and rapid, emotional, experiencing brain processing (Marshall, 2015). The latter is skilled in making decisions, but evolved to measure immediate threats, but not slow alterations taking place through generations and personal aspects are required for environmental problem-solving (Miller, 1982). Therefore, a rapid hands-on science communication tool may be useful for promoting environmental attitudes.

About 1/3 of American science teachers convey dubious messages emphasizing both anthropogenic and natural causes for CC and their insufficient knowledge of the underlying science principles may impede effective teaching

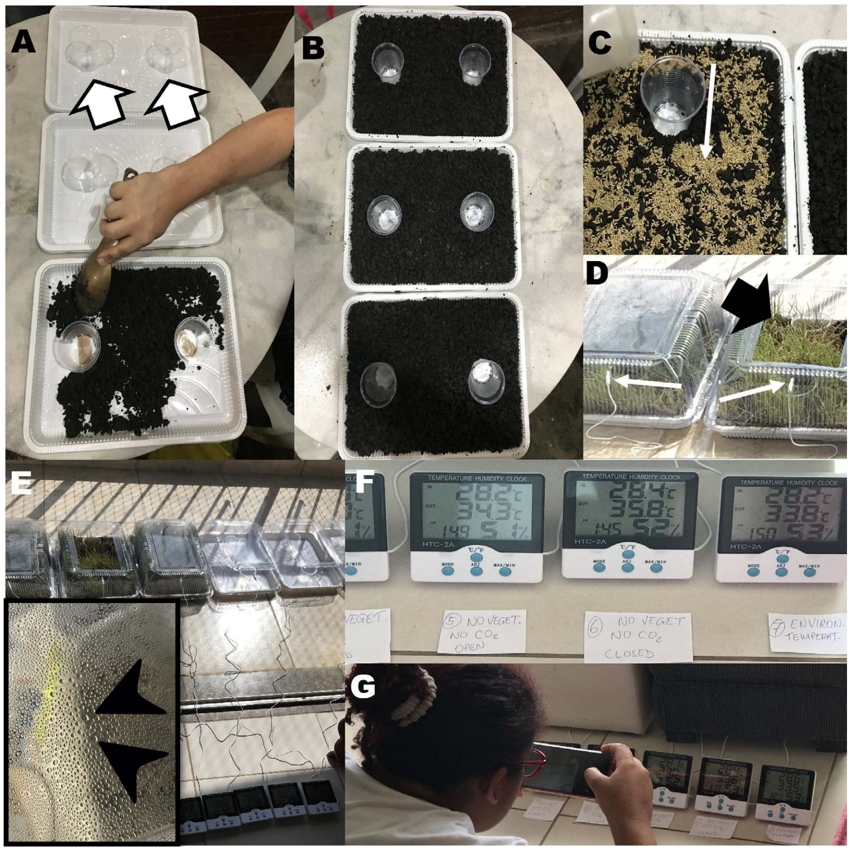

Figure 8. In experiments performed in Niterói, Rio de Janeiro (Latitude: −22˚53'00", Longitude: −43˚06'13"), humus-rich earth was added to reused, disposable packaging for cake transport (A). Two spaces were left where disposable cups were placed with water for adding or not effervescent tablets that release CO_2 (B) and seeds of golden birdseeds (*Phalaris canariensis*) were planted (C, arrow) and allowed to germinate (D). The sown boxes were watered daily for 30 - 35 days before experiments. Other boxes had cover top removed ((D), thick arrow) and/or remained empty (E). Open and closed packages were exposed to the sunlight in the presence or absence of CO_2 (E). Thermohygrometers with sensor probes inserted in each box lateral hole, were used to measure temperature and humidity at different times ((E)-(G)) and one suspended free in the air for determining environmental conditions. Particularly the vegetation-containing boxes formed water (vapor) drops on the inner surface of the cover ((E)—inset, arrowheads).

(Hackett, 2016; Plutzer et al., 2016). The situation may be similar or worse in other parts of the world. Thus, effective education/communication activities are urgently required, not only in schools and in continuous education but also for science literacy must be designed for public to take action on CC.

Practical activities may be not significantly effective (Abrahams & Millar, 2008), particularly whenever simple tasks or procedures following schemes of work and worksheets, in the so-called “recipe style” tasks. Students and teachers that follow toolkit manuals and/or detailed lesson plans may be enthusiastic (Kellner, 2017), but possibly not properly engaged in the creative science-making process. Alternatively, cooperative, hands-on activities focusing real world problems may be more attractive (Alper, 1993; Kock et al., 2016).

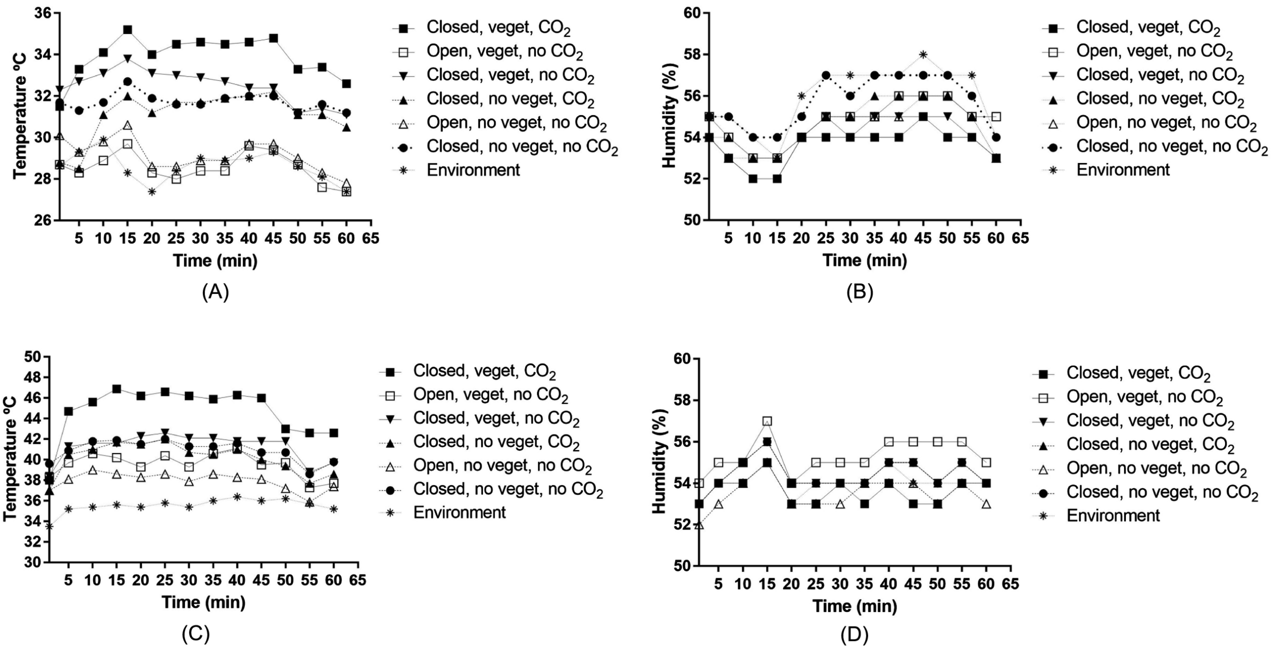

Figure 9. Temperature ((A), (C)) and humidity ((B), (D)) measured with digital thermohygrometers every 5 min. for 60 min. under different conditions as a function of time, in open or closed system, with or without vegetation and CO_2. In (A) and (B), each box received one effervescent tablet per plastic cup containing 100 mL water. In (C) and (D), each box received two tablets per cup with 50 mL water. The experiments were performed in both cloudy ((A), (B)) and sunny ((C), (D)) days.

In this case, it is possible to develop a framework where they get acquainted to the science endeavor, as proposed by the LMESN creator Prof. Leopoldo de Meis. In these activities, the experimental design and planning are previously discussed by teachers and students, and even during the experiment performing, adaptations may be carried out. It is noteworthy that the experiments were carried out focusing the problem i.e. global warming and CC and the method for testing hypothesis is developed with the students that become enthusiastically engaged in the named Creative Education (Ageyev, 2012; Lee, 2013). Nevertheless, Creative Education was reported to be declined in Rio de Janeiro mostly due to diminished investments and infrastructure shortage (Jesus et al., 2019). Thus the low-cost activity described here is valuable as it can be performed even in schools devoid of proper laboratories.

The present activity began in a LMESN event, that employ a problem-based learning methodology or inquiry-based, problematizing method and experiential learning (Kolb, 2014), in which the questions or problems, may lead to the formulation of hypotheses which can be tested by designing and performing simple experiments, using recycled/reused or inexpensive materials. The activities are not only designed by local teachers and students, but particularly focused according to the population's interests/concerns in scientific and/or health topics which are presented as the attendance poses questions at the beginning of the course. In Southern Brazil, mainly due to European colonization, the low skin pigmentation of German, Italian and Portuguese descendants raise a concern about skin cancer and the ozone layer. Therefore, the questions led us to approach the CC in a simple low-cost activity, although ozone layer loss is only indirectly connected to CC (Lindsey, 2016). The schoolteachers/students are encouraged to prepare and execute their own experiments in school settings, with only minor logistic assistance from the LMESN team, which solely acted (and declared themselves) as "technicians" assisting the "researchers" (i.e. local students and teachers).

CC education provides significant opportunities for interdisciplinarity promotion (McCright et al., 2013), but in middle school it is usually taught in geoscience or earth science, eventually not considered as laboratory or rigorous science (Foy & Foy, 2017). Therefore, the present activity may be relevant for comprising a low-cost experimental/laboratory activity leading to a clearly transdisciplinary approach with physics, chemistry, earth sciences and biology courses. The experiments reported here allow the separate testing of different variables independently. Cigarettes may be the source of smoke containing carbon monoxide, which is a poor greenhouse gas, but can influence the stability of other gases. This and other points may be discussed involving chemistry, physics, geography, biology and social studies (Passow, 2022) teachers, in a *bona fide* transdisciplinary approach, as according to US National Science Teacher Association, the theme integrates many different sciences (NSTA, 2020). The large cake boxes maybe used with plants, in order to permit testing the eventual role of vegetation as well as soil in the dynamics of temperature and humidity variation. In case an electronic hygrometer is not available a psychrometer may be constructed using two identical bulb thermometers (Carson, 2007).

In the present experiments, using both analogic and digital thermometers, we observed enhanced temperatures (*circa* 4˚C), within the closed cake boxes, as compared to the values obtained with the open ones or on free thermometers (environmental measurements), particularly whenever CO_2-releasing effervescent tablets were employed (up to 6˚C higher), indicating that the greenhouse effect could be mimicked by this homemade (or "school-made") system. In addition, in experiments both under sunny and shaded conditions, the high temperatures were observed in the closed vegetation with or without CO_2 (effervescent tablets added), as compared to the closed boxes with CO_2 but no vegetation. This fact may be due, at least in part, to temperature-dependent exponentially increased in soil microbiome respiration rate, leading to enhanced CO_2 efflux (Fang & Moncrieff, 2001; Lloyd & Taylor, 1994). In addition, increased CO_2 can enhance soil organic carbon and so, microbial biomass, enhancing CO_2 production (Jansson & Hofmockel, 2020). Besides, the closed boxes with vegetation and CO_2 also showed lowered air humidity, possibly because of the vapor condensation forming water drops on the inner surface of the cover (shown in **Figure 8**), as the free air temperature was significantly lower. Therefore, the system may allow discussions about temperature, clouds and rain formation, including the increased precipitation under CC. It is noteworthy that the present system can simulate the fundaments that underlie climate changes triggered by CO_2 release, water evaporation and cloud formations, pollution, etc., but these climate system events are remarkably complex, being influenced by geography, winds, sea currents, etc.

The digital thermohygrometers allowed quick and continuous measurements, which were suitable both for use in science fairs and exhibitions as well as introducing other variables such as cigarette smoke, shading, etc. Continuously assessed temperatures and humidity allow kinetic analyses, under dynamic conditions. The observation of decreased temperatures when a tree or a cloud shades the system indicates that the model can be used to approach heat-retaining properties of water and soil that may be used to focus the temperature variation by the seashore lakes etc., influencing the local biomes. Also, at this point physics, earth science and biology teachers may cooperate in transdisciplinary approaches.

An analogous nice hands-on activity focusing on global warming and greenhouse gases was previously developed (Keating, 2007), nevertheless, this activity used soft drink (Coca-Cola®) as the CO_2 source, but the students, mention the author, take short time and just gentle agitation to remove the CO_2. Keating (2007) suggested that "strong agitation [not easy in a beak jug or beaker] be used for at least two minutes", but it also seems a short period as (Strickhouser et al., 2017) used several hours for decarbonating. Such beverage could influence the system temperature by absorbing sunlight radiation mainly because of its caramel dark color, which may be different among nations, so the CO_2 concentrations may differ as well. Therefore, the use of effervescent tablets in our experiment did not significantly alter the water appearance, so the negative control is performed with no tablet addition. Furthermore, the use of a medicine with fixed and known composition may grant more reproducibility to the experiment, even among different countries. In addition, the cake boxes shape is suitable for sunlight irradiation (high surface/volume ratios), contrary to curved surfaces of PET bottles. On the other hand, the bottles may be tightly sealed with rubber stoppers.

Another activity was reported in an exciting and comprehensive book on ideas for experiments and science fairs by Mary Kay Carson (2007). In this experiment 2 identical tall, uncapped container, which may be quart tubs, cans, milk/juice, carton boxes, etc., partially filled with soil with inserted thermometers. One of the containers has tightly covered the top with plastic wrap and the containers are set under different kinds of lamp such as incandescent, florescent, halogen and the temperatures measured are plotted. The author stated that: "The plastic wrap represents the heat-trapping greenhouse gases in the atmosphere, but is not a perfect model for how the atmosphere traps heat since gases absorb and radiate heat back." In addition, the lamp at low distance will presumably heat the system via convection rather than radiation.

In a similar approach, cut and covered or uncovered plastic bottles illuminated by incandescent light bulb were used to simulate the greenhouse effect (Strickhouser et al., 2017). Nevertheless, the use of incandescent or dichroic lamps could raise some reservations about the simulation of the sunlight by such devices. Therefore, the use of a sunbathed cakebox can pose the advantage of using the sun irradiation *per se*, but the disadvantage of being limited by weather conditions and time of the day. Sunlight is easily accessible in underdeveloped tropical nations.

The simple procedures using everyday material available for the lay citizen allows the reproduction of the experiments at home with children, elderly, etc. In fact, we performed some of them at home and during the COVID-19 pandemic. Therefore, such kind of citizen science-like or yard science activity could help promoting scientific literacy and interest, particularly because as Martin Luther King Jr. stated "Seeing is not always believing" and according to Confucius (551-479 BCE) "I hear and I forget. I see and I remember. I do and I understand." Therefore, as students often show poor scientific argumentation skills (Choi & Shepardso, 2017), practical hands-on activities testing basic CC mechanisms via simple experiments may comprise a valuable tool for the comprehension of scientific method and data interpretation. Saylan and Blumstein (2011) showed that awareness is not always associated to action and the authors indicate that successful education interventions are based on encouraging imagination, open-minded experimentation and hands-on projects besides contacts with nature. Therefore, the present activity is promising since students and general public may experience a simple hands-on activity testing different variables in a creative and clearly interactive manner. These authors also mention teacher's motivation, as well as community involvement and support. The former may be easily achieved during experimental performance by enthusiastic students and the latter may be brought by activities involving students' families and communities, such as science fairs. Thus, the present activity may promote CC understanding by students and communities, possibly stimulating the population's engagement in pro-environmental behaviors.

5. Conclusion

The present study demonstrates the development of a simple low-cost, homemade activity to simulate global warming, permitting to approach of the role of CO_2 on the air temperature, humidity and the pollution or vegetation effects on the system. The model may be used in school settings, science fairs or Saturday/yard citizen science. The human brain is not wired for responding to slow threats, such as climate change. Here we present an instantaneous DIY climate change system so that the general public may witness and comprehend the process's basic mechanism, therefore may be engaged in the fight for environment-friendly practices. Since many students, teachers and public displayed excited looks and enthusiastically joined and remarked on the activity, it is possible to infer a widespread acceptance at the schools.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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