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**Heatwaves Awareness Education through Online Learning (HEAT)**

## WP2 - Deliverable n. 2.1b

## Title:

# Analysis of Current Climate Change Education Frameworks: Students' and Teachers' misconceptions about climate change, global warming and heatwaves

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## Aim of the Deliverable

The aim of this deliverable is to present students' and teachers' misconceptions about climate change, global warming and heatwaves. In the first part of this deliverable the authors provide definitions of the term heatwaves and present their connection with climate change and global warming. This is an important part as the majority of misconceptions start when somebody tries to define a concept, a term or an idea. In the second part common misconceptions about the three meanings are presented. This text as well as the bibliography in which it is referred will be the basis in which programs and materials will be built within this project.

## Introduction

Heatwaves are widely acknowledged as a result of climate change (Meehl & Tebaldi, 2004) and pose a significant health risk, particularly to the elderly (Cheng et al., 2018) and those residing in urban settings (Fernandez Milan & Creutzig, 2015; Macintyre et al., 2018). Despite their impact on our lives (WHO, 2004) a universally accepted definition of heatwaves has yet to be established (Smith et al., 2013)[1] (Table 1). This is partly due to the diverse geographical factors that influence the definition of heatwaves, as well as the variability in the health effects experienced by individuals in different regions, as they possess varying levels of adaptation to extreme natural events (Xu et al. 2016). The EuroHEAT project (Improving Public Health Responses to extreme weather/heat-waves), developed a standardized definition of a heat wave event for Europe as the following (D'Ippoliti, 2010):

1) periods of at least two days with Tappmax (maximum apparent temperature) exceeding the 90th percentile of the monthly distribution or
2) periods of at least two days in which Tmin (minimum temperature) exceeds the 90th percentile and Tappmax exceeds the median monthly value.

The World Meteorological Organization (WMO) defines a heat wave as a period during which the daily maximum temperature exceeds for more than five consecutive days the maximum normal temperature by 5 degrees Celsius, the normal period being defined as 1961–1990 (IFRC, UN OCHA & RCRC Climate Center, 2022). In Greece, the National Meteorological Service defines a heatwave as a situation where the maximum temperature reaches or surpasses 39°C, the minimum temperature exceeds 26°C, there is a narrow temperature range, mild winds, and persistently high temperatures prevail for at least three consecutive days across a wide geographical area (Lavi, 2016).

[1] For a detailed review of the various heatwaves definition see Xu et al. (2016).

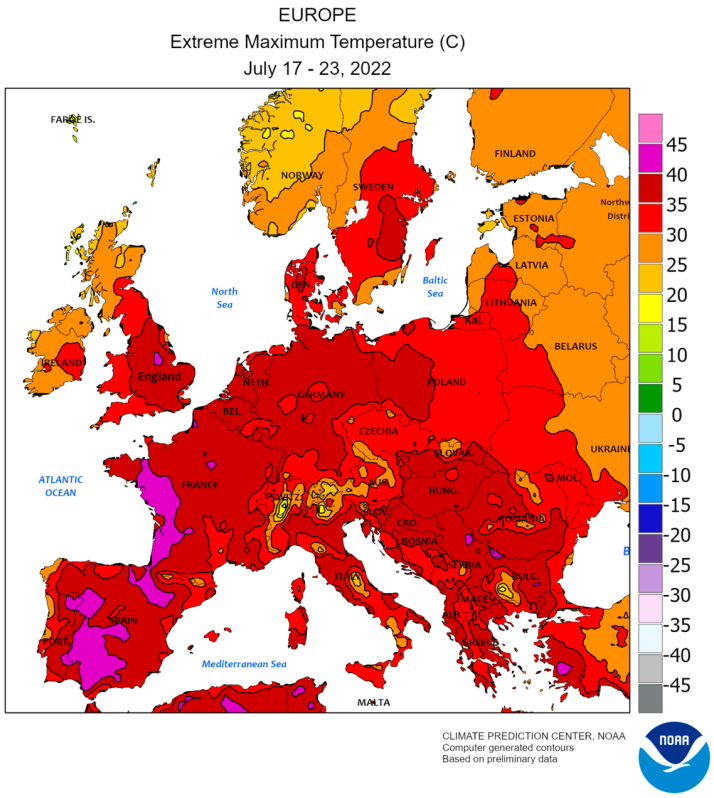


**Figure 1.**: Map which shows thermal waves the heat Europe. Extreme maximum temperature (°C) for July 17 to 23, 2022 in Europe, NOAA - https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/wcmax1.png, public domain

**Table 1.** Definitions before 2012 about heatwaves (Kent, et al., 2014, p. 152).

**Table 1.** Summary of data on HIs, PTB ($n$ = 60,466), and NAD ($n$ = 301,126) in 640 Alabama ZIP codes during 1990–2010.

| HI | Definition | Reference | HI days/year/ ZIP [$n$ (%)][a] | PTB [$n$ (%)] | NAD [$n$ (%)] |
|---|---|---|---|---|---|
| HI01 | Mean daily temperature > 95th percentile for ≥ 2 consecutive days | Anderson and Bell 2011 | 1.34 (0.9) | 652 (1.1) | 2,678 (0.9) |
| HI02 | Mean daily temperature > 90th percentile for ≥ 2 consecutive days | Anderson and Bell 2011 | 5.41 (3.5) | 2,373 (3.9) | 10,463 (3.5) |
| HI03 | Mean daily temperature > 98th percentile for ≥ 2 consecutive days | Anderson and Bell 2011 | 0.18 (0.2) | 111 (0.2) | 444 (0.2) |
| HI04 | Mean daily temperature > 99th percentile for ≥ 2 consecutive days | Anderson and Bell 2011 | 0.01 (0.0) | 1 (0.0) | 11 (0.0) |
| HI05 | Minimum daily temperature > 95th percentile for ≥ 2 consecutive days | Anderson and Bell 2011 | 0.08 (0.1) | 44 (0.1) | 104 (0.0) |
| HI06 | Maximum daily temperature > 95th percentile for ≥ 2 consecutive days | Anderson and Bell 2011 | 3.54 (2.3) | 1,610 (2.7) | 7,385 (2.5) |
| HI07 | Maximum daily temperature ≥ 81st percentile every day, ≥ 97.5th percentile for ≥ 3 nonconsecutive days, and consecutive day average ≥ 97.5th percentile | Peng et al. 2011 | 1.77 (1.2) | 839 (1.4) | 4,106 (1.4) |
| HI08 | Maximum daily apparent temperature[b] > 85th percentile for ≥ 1 day | Hattis et al. 2012; Steadman 1984 | 19.33 (12.6) | 8,333 (13.8) | 37,169 (12.3) |
| HI09 | Maximum daily apparent temperature[b] > 90th percentile for ≥ 1 day | Hattis et al. 2012; Steadman 1984 | 10.91 (7.1) | 4,681 (7.7) | 21,018 (7.0) |
| HI10 | Maximum daily apparent temperature[b] > 95th percentile for ≥ 1 day | Hattis et al. 2012; Steadman 1984 | 3.51 (2.3) | 1,568 (2.6) | 6,826 (2.3) |
| HI11 | Maximum daily temperature > 35°C (95°F) for ≥ 1 day | Tan et al. 2007 | 1.43 (0.9) | 497 (0.8) | 2,276 (0.8) |
| HI12 | Minimum daily temperature > 26.7°C (80.1°F) or maximum daily temperature > 40.6°C (105.1°F) for ≥ 2 consecutive days | Robinson 2001 | 2.90 (1.9) | 1,203 (2.0) | 5,701 (1.9) |
| HI13 | Maximum daily heat index[c] > 80°F for ≥ 1 day | Rothfusz 1990; Steadman 1979 | 125.47 (82.1) | 50,176 (83.0) | 245,833 (81.6) |
| HI14 | Maximum daily heat index[c] > 90°F for ≥ 1 day | Rothfusz 1990; Steadman 1979 | 78.26 (51.2) | 31,495 (52.1) | 151,189 (50.2) |
| HI15 | Maximum daily heat index[c] > 105°F for ≥ 1 day | Rothfusz 1990; Steadman 1979 | 3.35 (2.2) | 1,368 (2.3) | 5,581 (1.9) |
| HI16 | Maximum daily heat index[c] > 130°F for ≥ 1 day | Rothfusz 1990; Steadman 1979 | NA | NA | NA |

NA, not applicable.
[a]Percentages of HI days/year/ZIP code were calculated using the 153 days in May–September as the denominator. [b]Apparent temperature is a function of air temperature, humidity, wind speed, and solar radiation. [c]The HI is a function of air temperature and humidity, parameterized to take account of other environmental factors.

The above efforts to define heatwaves are indicative of the importance of this phenomenon which scientists, even 20 years ago, had predicted that would increase in the future as climate change progresses (Meehl & Tebaldi, 2004) and they were

proven right (Marx et al., 2021; Smith et al., 2013). According to the European Environment Agency "Urban areas are especially vulnerable to increasing heat stress because of the 'urban heat island' effect. Extreme heat also affects transport and energy infrastructure, agriculture and biodiversity, and it increases the likelihood of wildfires."[2]
During the mid-to-late '80s an anthropogenic climate change appeared in the public agenda (Moser, 2010). However, there still is today a significant amount of people who do not believe/understand the role of humans to climate change. In the USA, only 57% of American teens believe that climate change is caused mostly by humans (Leiserowitz, 2010).
Reynolds et al. (2010) found that laypeople's mental models, although slightly better, have not changed much since 1992 when Read et al. (1994) carried out a similar survey.
Seventh grade students cannot make conceptualizations of climate change and they cannot connect it to the greenhouse effect (Shepardson et al., 2009). Even when knowledge does exist, this is often fragmentary (Gambro & Switzky, 2010; Read et al., 1994).

## Misconceptions about Climate Change, Global Warming and Heatwaves

Global warming and climate change are the major causes of heatwaves but still there are people who do not accept this causal relationship and they tend to believe that **heatwaves are due to natural causes** and **a natural variability of the climate system** (Bostrom et al., 1994; McCaffrey & Buhr, 2008). They tend to identify them with warm weather. However, heatwaves are not simply hot weather, as we can clearly see from the above mentioned various definitions. They are periods of unusually high temperatures, which although are characteristic of heatwaves, are more accurately defined as prolonged periods of excessively hot weather that extend beyond typical seasonal norms.
This argument about heatwaves being just a variability of the climate appears more and more during the last years due to the way the topic is being presented in the media (Sampei & Aoyagi-Usui, 2009; Strauss et al., 2022). Some people even totally **ignore humans' role** in the increase of greenhouse gasses attributing this to the reduction of the ozone layer (Satriadi et al., 2019) and some believe that recent **global warming is caused by the sun** (Chang & Pascua, 2016). Many do not realize that the greenhouse effect is a natural phenomenon and it is the anthropogenic greenhouse gas contribution that intensifies it leading to climate change (Arslan et al., 2012). Other chiefly conflate the climate change and ozone depletion (Lambert et al. 2012; Ratinen et al. 2012; Versprille and Towns, 2015; Chang and Pascua, 2016; Varela et al. 2018).
Misconceptions that people have about climate change might significantly influence their actions and the environment (McNeill & Vaughn, 2012). A common misconception among the public in Europe and USA reported by many researchers is that the earth's mean temperature is rising because of **the thinning in the ozone layer** (Chowdhury et al., 2012; Lorenzoni & Pidgeon, 2006). The most prominent conceptual model supporting this misconception is that "the ozone depletion allows more of the sun's energy to pass through the atmosphere (Dupigny-Giroux, 2010; Foss and Ko, 2019; Stevenson et al., 2014)" (as mentioned in Milovanovic et al., 2022). This misconception has been found even among senior engineering

[2] eea.europa.eu/publications/europes-changing-climate-hazards-1/heat-and-cold/heat-and-cold-extreme-heat

students in the U.S.A. (Shepardson et al., 2009), pre-service teachers in the USA (Arslan et al., 2012) and the Canadian general public (Chowdhury et al., 2012), just to mention some. Another misconception is that **air pollution in general** - and not the specific greenhouse gasses - **causes climate change** (Bostrom et al., 1994)[3]. (Table 2)

**Table 2.** Common misconceptions about global warming, ozone layer and greenhouse effect.

- Global warming caused by depletion of the ozone layer;
- Global warming will cause skin cancer;
- Global warming can be reduced by limiting on chemical waste released into rivers;
- Global warming was caused by climate change.
- The carbon dioxide which can cause the increasing of the global warming.
- Using public transportation reduces the depletion of the ozone layer.
- Acid rain is a result of global warming;
- The ozone layer protected the earth from the acid rain.
- Carbon dioxide (CO2) had eroded the ozone layer in the stratosphere.
- The greenhouse effect is not a natural phenomenon but man-made.
- The greenhouse effect is a phenomenon that is truly dangerous to humans; and
- The ozone layer worked as a protector of UV light. Thus, it can regulate climate change and control the phenomena of the greenhouse effect.
- Increased greenhouse gases were caused by depletion of the ozone layer.
- The depletion of the ozone layer was caused by carbon monoxide.
- The greenhouse effect is not a natural but man-made phenomenon,
- The ozone layer is the layer involved in the process of the greenhouse effect.
- The climate is always changing or it has changed many times in the past before humans began burning coal and oil. So there is no reason to believe humans are causing warming today.
- The world has been cooling for the past decade; or, Global warming stopped in 1998 or 2002 or {insert preferred year}.
- There is no scientific consensus on the existence or causes of global climate change.
- Scientists predicted global cooling in the 1970s. Since they were wrong about that, there is no reason to believe they are right about global warming.
- Atmospheric water vapor is the heat-trapping gas that is primarily responsible for global warming.
- Climate change is just part of the natural cycle.
- Changes are due to sunspots/galactic cosmic rays.
- $CO_2$ is a small part of the atmosphere – it can't have a large heating affect.
- Climate models are unreliable and too sensitive to carbon dioxide.
- Scientists manipulate all data sets to show a warming trend.

[3] For a more in-depth presentation of climate change misconceptions see (Chang & Pascua, 2016; Choi et al., 2010; McCaffrey & Buhr, 2008; Satriadi et al., 2019).

Regarding heatwaves and peoples' perceptions about them, many **are not recognizing the risk of a heatwave as they don't think it is possible to happen in general or not possible to happen in their region specifically**. As Chowdhury et al. (2012) showed, in Canada 30% of the respondents were not aware of such a heat wave risk. It seems that the heatwaves' risk perception varies among people from different countries or even among regions of the same country (Huang et al., 2018).

Ekpoh (2011), Khalid (2000) and Summers et al. (2000) focused on the misconceptions about heatwaves that students and teachers might hold: (Table 3)

**Table 3.** Common misconceptions about heatwaves among students and teachers.

- Heatwaves are not due to natural causes
- Heatwaves are not a natural variability of the climate system
- Humans are the major causes of heatwaves as they contribute to the increase of greenhouse gasses attributing
- The increase of greenhouse gasses is not due to the reduction of the ozone layer
- Recent global warming is caused by human activities and is not caused by the sun
- The greenhouse effect is a natural phenomenon
- The anthropogenic greenhouse gas contribution intensifies the greenhouse effect leading to climate change.
- The thinning of the ozone layer is not causing earth's temperature to rise.
- It is not air pollution in general that causes climate change but the specific greenhouse gasses.
- Heatwaves are not a risk for specific regions but are possible to happen in any region.

Besides the misconceptions regarding heatwaves as a natural phenomenon, lots of people do not realize the risk that heatwaves pose for their health, especially the elderly.

## Can education eliminate Misconceptions?

The International Federation of Red Cross and Red Crescent Societies has published a book about the five things humanitarians need to know about extreme heat (IFRC, UN OCHA & RCRC Climate Center, 2022) as it is evident from the data that heatwaves are a major cause of suffering and death. In Portugal, in 1999, a system was created to conceive and operate an alert system for heatwaves and to study their characteristics and effects (Nogueira et al. 2005). Such systems have since been developed in many countries. However, education is the key in preparing people to protect themselves and their families, friends, neighbors and farms during a heatwave as if they are not trained to listen carefully to the early warning systems and be familiar with actions they should take to avoid the health hazards of a heatwave they would still be vulnerable[4].

[4] https://www.ifrc.org/our-work/disasters-climate-and-crises/what-disaster/heat-waves#lg=7276&slide=0

Reasons for all the above misconceptions or risk perceptions can be:

- lack of knowledge or lack of interests for topics not directly related to their everyday lives (Lorenzoni & Pidgeon, 2006)
- the way these topics are presented in the media (Carter, 2006; Strauss et al., 2022)
- the fact that some cannot discriminate between climate and weather and just think that such events as the heatwaves are occasional extreme events not related to climate (Gowda et al., 1997).

Political beliefs often are an obstacle in adopting scientific ideas instead of misconceptions (Fleming et al., 2021). As we can see in Figure 1.a knowledge about climate change and heatwaves by itself is not sufficient as even people who possess great knowledge about environmental problems can also show little concern (Malka et al., 2009). Education should also focus on developing students' self-efficacy, raise their concern and lead them to recognize the perceived harm. According to Stevenson et al. (2014) (Figure 2.b) climate change knowledge and acceptance of anthropogenic global warming are all important for a risk perception of climate change.

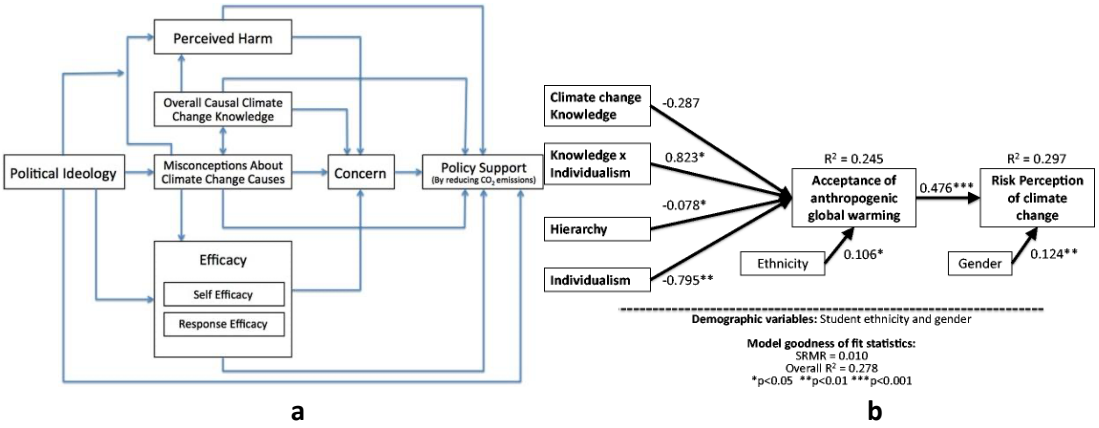


**Figure 2.** General models of how certain factors interact and lead to concern and support for policies reducing $CO_2$ emissions. (1.a: Fleming et al., 2021, p. 160, 1.b: Stevenson et al., 2014, p. 296).

Therefore, a need to educate people about climate change, its connection to heatwaves and how people can act against climate change, as also on how to act effectively to protect themselves from heatwaves (Williams et al., 2019) is evident. But education, that relies not only on knowledge development but also in developing an interest in science, as the latter has been proven to have long-term effects with increased trust in climate scientists (Motta, 2018), therefore could improve people's perceptions about heatwaves and climate change.
A climate change curriculum is needed that would address these misconceptions and convince students that their actions are important in fighting climate change (McNeill & Vaughn, 2012). Educational materials targeting heatwaves mitigation and risk perception should be developed focusing on the misconceptions that students and teachers might hold (see Table 2) and be presented in a way that:

- it includes knowledge &

- presents topics that are directly related to students' and teachers' everyday lives (Lorenzoni & Pidgeon, 2006),
- takes under consideration the way these topics are presented in the media and debunk them if needed (Carter, 2006; Strauss et al., 2022),
- it discriminates between climate and weather &
- it makes clear that events as the heatwaves:
    - are not occasional extreme events unrelated to climate (Gowda et al., 1997).
    - also affect indoor besides outdoor activities (Ban, et al. 2019).
    - pose a risk to anyone besides the elderly or those with pre-existing health conditions

The main messages that curricula and educational materials should send are the following (IFRC, UN OCHA & RCRC Climate Center, 2022):

- Stay informed - monitor weather, listen to the radio and follow instructions
- Avoid direct exposure to the sun
- Protect yourself with appropriate clothing
- Stay hydrated
- Be aware of the symptoms of heat induced sickness
- Connect with your peers
- Stay aware of people and animals at risk around you
- Cool yourself down
- Prepare tools to build temporary cooling/shade structures
- Protect your living space
- Adapt your eating and drinking habits to stay hydrated
- Modify daily routines

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