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Kindergarten Student Teachers' Knowledge Regarding Crucial Environmental Challenges

Abstract

Global warming and a decline in pollinating insects are among the most crucial challenges today and a sufficient degree of scientific literacy is required for citizens in order to understand these issues and take action for sustainable development in general. Several studies have investigated knowledge associated with the greenhouse effect and the effect of the ozone layer. These have deduced that despite improvement in teaching tools, a high proportion of pupils and students still confuse these two phenomena. Previous research has also shown that plant biology is a neglected subject and students struggle to differentiate between pollination and seed dispersal. This study investigates the understanding regarding the mechanisms underlying global climate change and pollination by conducting a survey with four classes of Norwegian kindergarten teacher students, at the beginning of the academic year (n = 103), and by asking follow-up questions after completed teaching (n = 111). It was observed that approximately 40 percent of the students confused the greenhouse effect with the effect of the hole in the ozone layer. One fifth of the students mentioned photosynthesis while describing the importance of the Sun for life on Earth. About one third of them connected pollen to plant reproduction and two thirds believed that pollen is seeds. A survey at the end of the academic year showed that a substantial proportion of the students displayed teaching resilience. These results can be interpreted in the light of constructivist learning theory and might partly be explained by the role mass media play in influencing scientific literacy. For future citizens to make informed decisions, ecological issues should be prioritised in education.

INTRODUCTION

Humanity, especially the next generation, will face several challenges linked to the environmental component of sustainable development. Among these, global climate change, due to increased levels of greenhouse gases in the atmosphere released by human activity, is probably the most important (Palmer & Smith, 2014). Greenhouse gas emissions pose a huge threat to humanity as they can intensify many hazards that humanity is vulnerable to and can occur simultaneously (Mora et al., 2018). These include heatwaves, drought, floods, fires, storms, and a rise in the sea level, which can have a negative impact on human health, food, water, infrastructure, economy, and security (Mora et al., 2018). In 1997, the United Nations Framework Convention on Climate Change adopted the Kyoto Protocol (UNFCCC, 1997) as an international agreement, in which industrialised countries commit to reduce carbon dioxide emission.

Another major environmental challenge is the decline of both wild and domestic pollinating insects (Potts et al., 2010), due to a combination of factors such as global warming (Scaven & Rafferty, 2013), changes in land use (Lazaro & Tur, 2018), and the use of pesticides in agriculture (Woodcock et al., 2016). Pollinators are necessary for plant reproduction as they facilitate fertilisation and are therefore imperative for the functioning of the ecosystem and crop production. Animal-pollinated crops contain most of nutrients such as lipids, and vitamin A, C, and E, which are an important part of the diet across the world. This indicates that there could be a potentially drastic effect on human nutrition as a consequence of decline in pollinators (Eilers, Kremen, Greenleaf, Garber, & Klein, 2011).

The plan of action for people, planet and prosperity, recommended by the United Nations (UN General Assembly, 2015) includes seventeen sustainable development goals that have to be achieved by 2030. Several of these emphasise on the need to promote and improve education related to sustainable development, and two of them are specifically relevant for this study:

Goal 12.8 states that by 2030, people across the world should have the relevant information and awareness for sustainable development and lifestyles that are in harmony with nature.

Goal 13.3 states that education must be improved to raise awareness and enhance human and institutional capacity to mitigate and adapt to climate change and introduce methods to reduce the impact of climate change and provide early warnings.

Norwegian students begin to learn about science in preschool itself. The kindergarten system in Norway does not emphasise on the 'school preparatory' work and playing is the primary activity in preschools. However, the Ministry of Education, in 2006 mentioned that, 'The aim is for children to begin to understand the significance of sustainable development, and an understanding of the interactions within nature and between humans and nature'.

The Norwegian Ministry of Education and Research (2013), as a part of the competence aims, has specified that at the end of the ten years of obligatory school, a student should be able to explain the main features of photosynthesis and the relationship between biotic and abiotic factors in a nearby ecosystem. The competence aims for the end of secondary school, state that students should be able to explain the importance of the ozone layer in relation with the radiation from the Sun, explain what the greenhouse effect is, and how human activities change the energy balance in the atmosphere.

This study investigates knowledge regarding the mechanisms that lead to global climate change and the importance of pollinating insects by conducting a survey with 103 students, training as kindergarten teachers, at the beginning of the academic year before the course began and again during the mandatory final written exam. According to the plan of action for people, planet and prosperity by the United Nations (UN General Assembly, 2015), it is assumed that this knowledge is essential for adult citizens to take action for sustainable development. Generally, science literacy is necessary to enable citizens to make informed decisions, not only while voting during political elections, but also on a daily basis as consumers (Directorate-General for Education, Youth, Sport and Culture, 1995).

Literature review

The first question ('What does (enhanced) greenhouse effect mean?') is intended to reveal the understanding that students have about the mechanism underlying global climate change and their responsibility as humans beings to control the release of greenhouse gases and their impact on the climate. Several studies have explored the knowledge that both pupils and students have regarding the greenhouse effect and the ability to distinguish between the greenhouse effect and the effect of the hole in the ozone layer (e.g. Andersson & Wallin, 2000; Boyes & Stanisstreet, 1993; Cordero, 2002; Hansen, 2010). These studies consistently identified confusion between ozone layer depletion and global warming in a large proportion of the sample. For example, Hansen (2010) examined the knowledge about the greenhouse effect and the effects of the ozone layer in Norwegian students in 1989, 1993, and 2005 and found that despite increasing focus in the media, improvement in teaching books, and changing curricula, during this period, the students were still confusing the two phenomena. Similar results have been found for school children in UK (Boyes & Stanisstreet, 1993), first year university science students in Australia (Cordero, 2002) and American pre-service high school teachers (Khalid, 2003). A study conducted in Singapore on secondary school students' alternative conceptions on climate change found that the percentage of students who believed that the ozone hole enhanced the greenhouse effect changed from 48 to 31 percent after they studied about climate change (Chang & Pascua, 2015). The authors conclude that alternative conceptions show resilience to teaching when new concepts come in conflict with previous knowledge. Although confusion between the greenhouse effect and the effect of the ozone layer has been documented previously in Norway, better awareness and improved teaching programmes in the last decade might have contributed to clarifying the issue further.

The second question ('Why is the Sun important for life on Earth?') aimed at exploring the students' understanding about the particular conditions that allowed life on Earth such as the distance from the Sun and the role that plants play in the ecosystem as primary producers. Plants (both terrestrial plants and algae) produce carbohydrates (for example, glucose, amid, and cellulose) from carbon dioxide (CO_2), water, and sunlight, through photosynthesis and release oxygen as a by-product. The phenomenon of 'plant blindness' and the general lack of interest in plants (Wandersee, 1986; Wandersee & Schussler, 1999) are known challenges when teaching plant biology in schools. However, plants have a fundamental role as primary producers of organic matter in the ecosystems (Clary & Wandersee, 2011). This provides support for all life on Earth and it is therefore critical that people understand the importance of plants (Lampert, Scheuch, Pany, Müllner, & Kiehn, 2019). Several studies investigated students and pupils understanding and misconceptions about photosynthesis (Canal, 1999; Marmaroti & Galanopoulou, 2006; Ozay & Oztas, 2003) and found that their initial ideas can be deeply rooted and difficult to change. However, we are not aware of any study that investigated students' understanding of the importance of the Sun for life on Earth.

The third question ('What is pollen?') is intended to investigate the students' knowledge about the mechanism of plant sexual reproduction. Approximately, 87 percent of plants pollinate with the help of animals (Ollerton, Winfree, & Tarrant, 2011) and the economic value of pollinators for sustainable crop production is estimated to be up to 153 billion € across the world (Gallai, Salles, Settele, & Vaissiere, 2009).

Understanding the function of pollen is a prerequisite to recognise the role that pollinating insects have in the functioning of the ecosystem and crop production, which in turn is important if any action has to be taken to address their decline. Previous research has shown that the students struggle to differentiate between pollination and seed dispersal (Lampert, Scheuch, Pany, Müllner, & Kiehn, 2019) although these conceptions appear crucial for understanding plant reproduction (Lampert, Mullner, Pany, Scheuch, & Kiehn, 2020).

METHODS

Study context

In Norway, to pursue kindergarten teacher education, a minimum of ten years of mandatory school (from the age of six years) and three years in high school, is a prerequisite.

The course in Natural Sciences, Environment, and Health at the Queen Maud University College extends across the fall and spring semesters, with several other courses (Norwegian, pedagogy, social science, religion and ethics, mathematics, and physical activity) and it includes sixty-one hours of teaching. The subjects taught include, ecology, biological diversity, sustainable development, and astronomy, among others. Most of the course work in Natural Sciences is taught during the second year of bachelor's study in kindergarten teacher education, and the average age of students is 21.8 years (±2.73). The university college has students from all over the country.

The course in Natural Sciences includes both theoretical teaching, nature excursions, and practical activities. During the course, students learn about plants systematics, reproduction, and the role of plants as primary producers in the ecosystems, both through standing lectures and by watching short documentaries. As a learning activity, the students also plant seeds in different conditions (for example, with and without access to sunlight) and study their development. Photosynthesis and the connection between insects and plants are also discussed while teaching about seasonality and how plants and animals adapt to it. During two of the forest excursions, the students collect flowers, and make a herbarium with at least thirty (correctly identified) wild plants. The issues related to the greenhouse effect and ozone layer are encountered twice during the course. The first time in the context of ecology and sustainable development, when the alternative energy sources are discussed and our ecological footprint is calculated. Then again, while learning about the different planets in the solar system and the factors (atmosphere thickness and composition, distance from the Sun, mass, and so on) that determine their average surface temperature.

Participants

In September 2018, before the course commenced, we asked the students from four classes (n = 103) in the second year of kindergarten teacher education (DMMH, Trondheim) to fill a volunteer questionnaire regarding their previous knowledge of Natural Sciences. Some students who did not attend the first session were not included in the pre-knowledge questionnaire, but took the final exam and are therefore included in the after-teaching dataset.

Data collection

To ensure anonymity, we did not collect personal data and hence could not link the questionnaire with the students' identity. The questionnaire included one multiple-choice question about the meaning of the term '(enhanced) greenhouse effect' and two open questions, where we asked the students to explain, in their own words, why the Sun is important for life on Earth and what pollen is. We then coded the answers from the open questions, into six different categories of increased knowledge (Table 1). Three categories where already defined for the multiple-choice question (one correct answer and two different alternative explanations, see Table 1).

For the mandatory written exam at the end of the course, in May, the same three questions were asked the same students from the four classes (n = 111) with one variation that the multiple-choice question regarding the greenhouse effect was also formulated as an open question (as the exam design could not include multiple-choice questions).

Finally, in November, after analysing the questionnaires, we presented the results to next year students and collected their opinions on what could be the causes of the outcome. This was not intended as part of the original study, as the data were collected *a posteriori* in an informal and non-systematic manner. However, we thought that first hand opinions from next year's students might help us getting insights about the causes of the outcome of the questionnaire.

Analysis

For the two open-ended questions, we tested significance of differences in students' response before and after the course with Pearson's chi-squared test. Statistical test were performed in R 3.6.1 (R Core Team, 2019).

Table 1. Open (1-2) and multiple-choice (3) questions given to the students at the beginning of the academic year and at the final exam in Natural Sciences.

Question	Categories of answers
1. What does (enhanced) 'greenhouse effect' mean?	**More UV radiation enters the atmosphere through the hole in the ozone layer that is protecting the Earth.**
	The quantity of CO_2 in the atmosphere increases and radiates back to the Earth the heath from the Sun.
	The Sun is becoming warmer and the temperature increases on the Earth.
2. Why is the Sun important for life on Earth?	**No answer or circular argument 'without Sun life cannot exist'**
	Warmth or 'without Sun there would be a new ice age'
	Warmth, light, D-vitamine (two causes)
	Warmth, light, D-vitamine (three causes)
	Photosynthesis
	Photosynthesis and other arguments
3. What is pollen?	**No answer**
	Substance causing allergy
	Flower dust
	Something from plants, spread by the wind, coming in spring
	Seeds or elements of reproduction
	Using the word 'fertilisation', 'sperm' of the plant

RESULTS

Greenhouse effect

Before the course began, more than half of the students (53 percent) answered the multiple-choice question regarding the greenhouse effect correctly, attributing this phenomenon to the carbon dioxide in the atmosphere that is radiating back the heat from the Sun. A rather large proportion of the students (39 percent) confused the greenhouse effect with the hole in the ozone layer, while 4 percent believed that the greenhouse effect is due to the Sun becoming warmer. Another 4 percent did not answer the question (Figure 1a).

When we asked this question again as an open question during the final written exam, 25 percent of the students answered correctly, both addressing the presence of greenhouse gases in the atmosphere and the fact that these gases radiate back to the Earth the heat from the Sun. One fifth (20 percent) of the students still confused it with the ozone layer and 46 percent gave an incorrect explanation, they spoke about pollution in general terms and did not mention the radiation of heat and greenhouse gases. Approximately 4 percent of the students confused it with either the photosynthesis or the water cycle and 5 percent did not answer the question (Figure 1b).

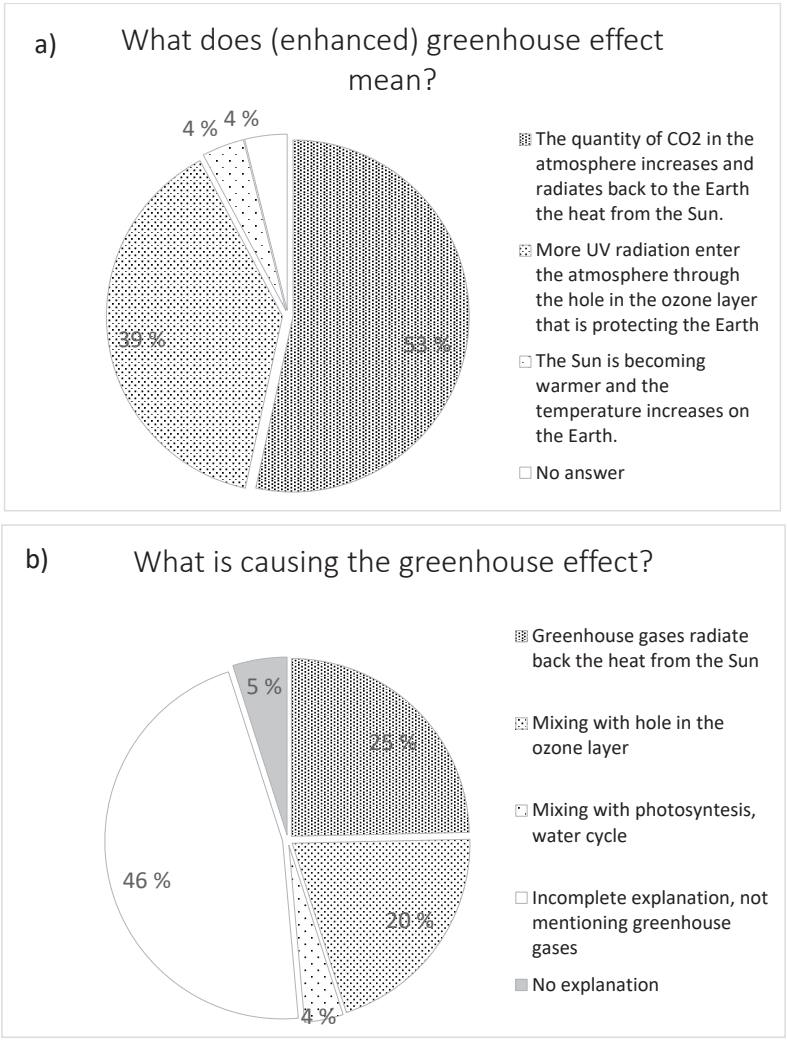

Figure 1. Answers given by students to the questions about greenhouse effect (a) before the course in Natural sciences had started (multiple choice question, n = 103) (b) at the final exam (open question, n = 111).

Importance of the Sun for life on Earth

Before the course began, less than 30 percent of the students mentioned photosynthesis and primary production from plants as the main source of all life on Earth. While 11 percent of the students failed to answer the question or used a circular argument such as 'without the Sun there could not be life on Earth', 33 percent mentioned that the Sun was important only because of the heat generated. One-fourth (24 percent) of the students mentioned two factors out of heat, light, and Vitamin D, and 3 percent mentioned all three. One-fourth (24 percent) of the students mentioned both photosynthesis and at least one of the other factors (Figure 2a).

After the course ended in May, there was a huge difference in the responses. We grouped the six original categories into three main categories (Figure 2b), those who mentioned photosynthesis and at least one other argument, those who only mentioned photosynthesis, and those who did not mention photosynthesis. The proportion increased for the first category from 24 to 70 percent, while for the latter it decreased from 68 to 24 percent. The change in percentage of students who mentioned photosynthesis was significant (Pearson chi-squared test = 48.38, df = 1, P < 0.001). The proportion of students who only mentioned photosynthesis remained almost stable (Figure 2b).

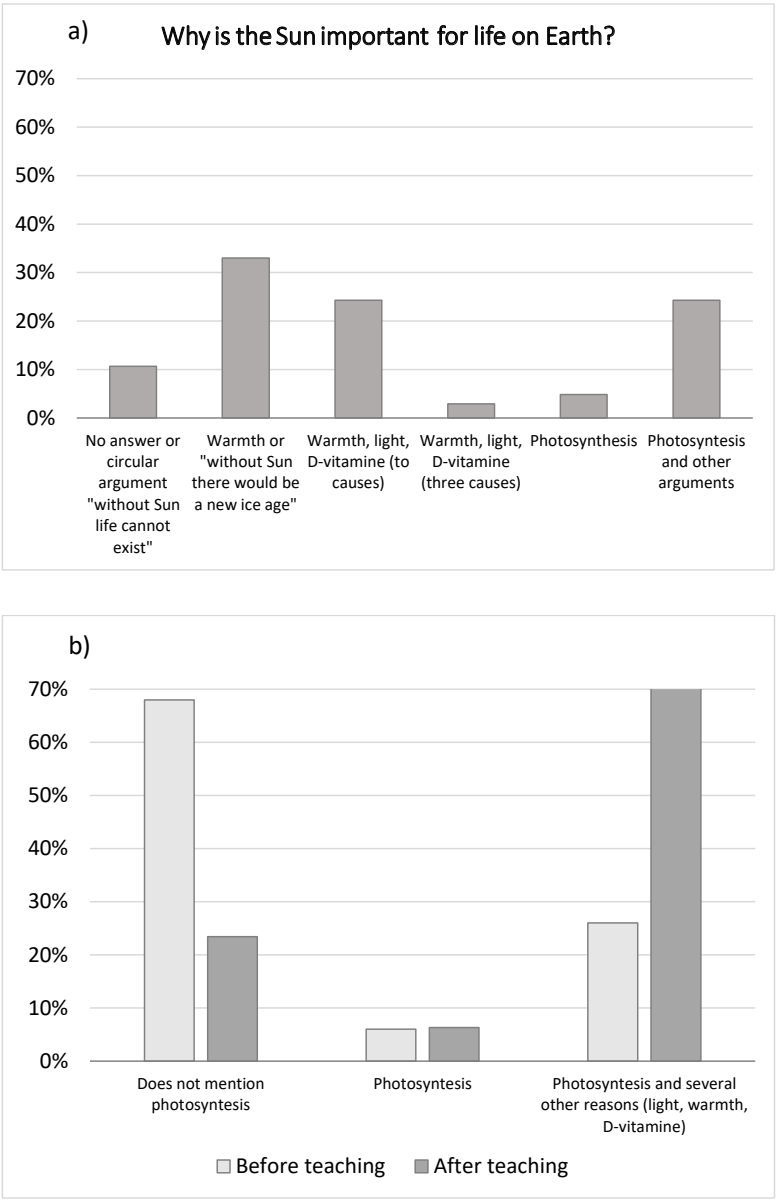

Figure 2. Answers to the open question about the reasons for Sun importance for life on Earth, a) before the course in Natural Sciences (n = 103), b) before and after the course in Natural sciences (final exam), with grouped categories (n = 111).

What is pollen?

When asked at the beginning of the academic year, a very low proportion (7 percent) of the students answered the question correctly (Figure 3). About one-fourth (24 percent) stated that pollen is linked in some way to plant reproduction, and almost half of the students mentioned 'flower dust' which is synonymous to pollen in Norwegian, but does not explain what the function is.

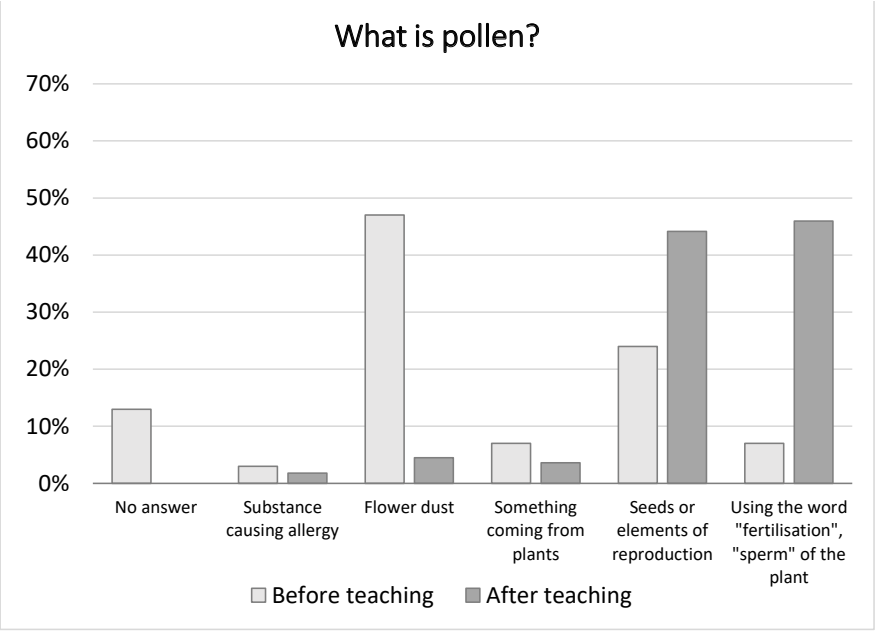

Figure 3. Answers to the open question about what is pollen before the course started (n = 103) and at the final exam in Natural Sciences (n = 111).

Ten percent of the students stated that pollen is something that comes from plants or causes allergies and 13 percent did not answer the question. At the end of the course, almost 90 percent of the students answered that pollen is involved in plant reproduction and 45 percent mentioned the word 'plant sperm', 'gametes', or 'elements for sexual reproduction'. After the course finished, the proportion of students who gave the generic answer, 'flower dust', decreased significantly and the proportion of students who answered correctly increased significantly (Pearson's chi-squared test = 89.89, df = 5, $P < 0.001$).

DISCUSSION

At the beginning of the academic year, 39 percent of the students confused the greenhouse effect with the hole in the ozone layer. This result is consistent with the findings of other similar studies conducted in Norway (Hansen, 2010), Australia (Khalid, 2003) and North America (Cordero, 2002). One of the first studies reporting confusion between these issues found that 64 percent of undergraduate students agreed that greenhouse effect is made worse by holes in the ozone layer (Boyes & Stanisstreet, 1993). The authors suggested that the students thought that holes in the ozone layer would allow increased penetration of solar heat. (Boyes, Chambers, & Stanisstreet, 1995) proposed that this misconception is common because it is not possible to have an experimental approach when

teaching about these issues. Nevertheless, greenhouse gases and the ozone layer are elements that are part of the atmosphere, outside our sight and daily concern. The ozone layer protects us from the dangerous UV-radiation. Ozone depletion and the ozone hole have led to worldwide concern regarding increased cancer risks and other negative effects. In 1987, a worldwide ban was imposed on the production of chlorofluorocarbons, halons, and other ozone-depleting chemicals (Montreal Protocol). The greenhouse effect and the role of the ozone layer came into political and media focus during the 1980s (Hansen, 2010). Several authors (Bell, 1991) have reported a general misunderstanding promoted in newspaper articles about the connection between the greenhouse effect and ozone layer, which might contribute promoting erroneous ideas. Moreover, information regarding these topics is constantly changing and textbooks might be outdated (Cordero, 2002). (Schreiner, Henriksen, & Hansen, 2005) suggested also that young people consider environmental protection an important goal, but they are not very interested in learning about climate change because they feel that they have little influence on global development.

More than half of the students answered the multiple-choice question about the greenhouse effect correctly at the beginning of the academic year, but only one-fourth gave a correct explanation of this phenomenon in the final exam.

It is difficult to compare the results of a multiple-choice test, where the students could have also guessed the answer (Cooper & Foy, 1967), with the responses to an open question. Therefore, we cannot draw conclusions about the impact of teaching. However, several studies have documented resilience in addressing misconceptions related to this subject. For example in Singapore, the percent of students who believed that the ozone hole enhanced the greenhouse effect showed an improvement after teaching about climate change (Chang & Pascua, 2015), but this was not dramatic (from 48 to 31 percent). The authors found that secondary school students continued to retain a number of alternative conceptions after teaching and suggested that this happens when new concepts come in conflict with prior knowledge. This type of results can also be interpreted in the light of the constructivism understanding of learning. This theory has dominated the science education for the last three decades. According to the constructivist theory, students' pre-conceptions influence their learning (Blais, 1988). This happens because learners build new knowledge upon the foundation of previous learning, through experiencing things and reflecting on those experiences (Bereiter, 1994). In this respect, previous knowledge and 'lay beliefs' play an important role in filtering experiences and building up new knowledge. This results also suggests that it is easier to activate earlier knowledge and correctly answer a multiple-choice question, rather than formulating with own words an *ex novo* explanation, even when the information has been newly revised to prepare for an exam.

When we presented the results of our test to next year students and asked them about their perception on why is it difficult to disentangle the greenhouse effect from the effect of the ozone layer, they gave the following reasons:

- Embarrassment in asking for further explanation on issues that everybody is expected to be acquainted with since they are frequently mentioned in the news.
- Greenhouse effect and information about the ozone layer are taught in a simplified way at primary school and are often taught together, as they are both associated with the atmosphere and are environmental issues.
- It is difficult to replace the knowledge that has been assimilated during the first years of school.
- The manner in which the greenhouse effect and the information regarding the ozone layer is presented on the internet may be confusing. Furthermore, it is difficult to distinguish between the sources presenting the scientific correct explanations and the incorrect ones.

When asked about why they do not mention photosynthesis when explaining the importance of the Sun for life on Earth, the students mentioned that an incomplete answer is not necessarily wrong and some students might have stopped giving further explanations after answering 'heat'

or 'light'. The same type or argument could explain why a number of them mentioned 'flower dust' when asked what pollen is.

In 1998, Wandersee and Schussler introduced the term 'plant blindness' meaning 'the inability to see or notice the plants in one`s own environment, leading to the inability to recognise the importance of plants in the biosphere and in human affairs' (Allen, 2003). The authors claim that most people ignore plants and rank animals as more important than plants, since educators tend to use animals as examples to teach basic biological concepts. This phenomenon might also explain why many of the students did not mention photosynthesis when describing the importance of the Sun for life on Earth and did not know what pollen is. However, the question about the Sun`s importance for life on Earth also demands the ability to connect different concepts that are generally taught independently in astronomy and biology.

Mostly, course work regarding the Sun and Earth focuses on information related to the solar system such as, the names of planets, day and night cycle, or seasonal change (Sharp & Kuerbis, 2006).

Photosynthesis and ecosystem functioning, and greenhouse effect and global warming, are certainly crucial topics to understand, if we are going to take action to ensure sustainable development. However, these are complex phenomena and cannot be experienced first-hand. It is also difficult to have an experimental approach while teaching them. Moreover, although environmental challenges are usually discovered by scientists, the primary role in promoting public awareness is played by the media (Likens, 2010; Schreiner, Henriksen, & Hansen, 2005). For example, websites on pollen allergies often use pictures of dandelion fruit as illustration of pollen (Lampert, Scheuch, Pany, Müllner, & Kiehn, 2019). In fact, one fourth of the students before being taught and almost half of them after teaching, recognised that pollen is an element of plant reproduction, but did not specify that it is the plant sperm or explicitly recognised it as plant seeds.

We conclude that more emphasis when teaching ecological issues and more effort to raise the awareness of teachers about pitfalls (such as misleading information in media) are necessary to help meeting the goal of improving education for sustainable development (UN General Assembly, 2015).

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REFERENCES

Allen, W. (2003). Plant Blindness. *BioScience, 53*(10), 926-926. doi:10.1641/0006-3568(2003)053[0926:Pb]2.0.Co;2

Andersson, B., & Wallin, A. (2000). Students' understanding of the greenhouse effect, the societal consequences of reducing CO2 emissions and the problem of ozone layer depletion. *Journal of Research in Science Teaching, 37*(10), 1096-1111. doi: 10.1002/1098-2736(200012)37:10<1096::Aid-tea4>3.0.Co;2-8

Bell, A. (1991). *The language of news media*. Oxford, UK; Cambridge, MA: Blackwell.

Bereiter, C. (1994). Constructivism, Socioculturalism, and Popper's World 3. *Educational Researcher, 23*(7), 21-23. doi:10.3102/0013189x023007021

Blais, D. M. (1988). Constructivism: A theoretical revolution in teaching. *Journal of Developmental Education, 11*(3), 2-7.

Boyes, E., & Stanisstreet, M. (1993). The Greenhouse-Effect - Childrens Perceptions of Causes, Consequences and Cures. *International Journal of Science Education, 15*(5), 531-552. doi:10.1080/0950069930150507

Boyes, E., Chambers, W., & Stanisstreet, M. (1995). Trainee Primary Teachers' Ideas about the Ozone Layer. *Environmental Education Research*, 1(2), 133-145. doi:10.1080/1350462950010201

Canal, P. (1999). Photosynthesis and 'inverse respiration' in plants: an inevitable misconception? *International Journal of Science Education, 21*(4), 363-371. doi: 10.1080/095006999290598

Chang, C.-H., & Pascua, L. (2015). The hole in the sky causes global warming: A case study of secondary school students' climate change alternative conceptions. *Review of International Geographical Education Online, 5*(3), 316-331. https://files.eric.ed.gov/fulltext/EJ1158061.pdf

Clary, R., & Wandersee, J. (2011). Our human-plant connection. *Science Scope, 34*(8), 32-37.

Cooper, B., & Foy, J. M. (1967). Guessing in multiple-choice tests. *British journal of medical education, 1*(3), 212-215.

Cordero, E. C. (2002). Is the ozone hole over your classroom? *Australian Science Teachers' Journal*, 34-39. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.588.8122&rep=rep1&type=pdf

Directorate-General for Education, Youth, Sport and Culture. (1995). *White paper on education and training: teaching and learning towards the learning society*. Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/d0a8aa7a-5311-4eee-904c-98fa541108d8/language-en.

Eilers, E. J., Kremen, C., Greenleaf, S. S., Garber, A. K., & Klein, A. M. (2011). Contribution of Pollinator-Mediated Crops to Nutrients in the Human Food Supply. *Plos One, 6*(6). doi:10.1371/journal.pone.0021363

Gallai, N., Salles, J. M., Settele, J., & Vaissiere, B. E. (2009). Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics, 68*(3), 810-821. doi:10.1016/j.ecolecon.2008.06.014

Hansen, P. J. K. (2010). Knowledge about the Greenhouse Effect and the Effects of the Ozone Layer among Norwegian Pupils Finishing Compulsory Education in 1989, 1993, and 2005-What Now? *International Journal of Science Education, 32*(3), 397-419. doi:10.1080/09500690802600787

Khalid, T. (2003). Pre-service high school teachers' perceptions of three environmental phenomena. *Environmental Education Research, 9*(1), 35-50. doi:10.1080/13504620303466

Lampert, P., Mullner, B., Pany, P., Scheuch, M., & Kiehn, M. (2020). Students' conceptions of plant reproduction processes. *Journal of Biological Education, 54*(2), 213-223. doi: 10.1080/00219266.2020.1739424

Lampert, P., Scheuch, M., Pany, P., Müllner, B., & Kiehn, M. (2019). Understanding students' conceptions of plant reproduction to better teach plant biology in schools. *Plants, People, Planet, 1*(3), 248-260. doi:10.1002/ppp3.52

Lazaro, A., & Tur, C. (2018). Land-use changes as drivers of pollinator declines. *Ecosistemas, 27*(2), 23-33. doi:10.7818/Ecos.1378

Likens, G. E. (2010). The role of science in decision making: does evidence-based science drive environmental policy? *Frontiers in Ecology and the Environment, 8*(6), E1-E9. doi:10.1890/090132

Marmaroti, P., & Galanopoulou, D. (2006). Pupils' understanding of photosynthesis: A questionnaire for the simultaneous assessment of all aspects. *International Journal of Science Education, 28*(4), 383-403. doi:10.1080/09500690500277805

Ministry of Education and Research. (2006). *Framework plan for the content and tasks of kindergartens*. (34 p.). Oslo: Ministry of Education and Research. Retrieved from https://www.udir.no/globalassets/filer/barnehage/rammeplan/framework-plan-for-kindergartens2-2017.pdf

Ministry of Education and Research. (2013). *Natural Science subject curriculum*. Retrieved from https://www.udir.no/kl06/NAT1-03/Hele/Komplett_visning/?lplang=eng&read=1

Mora, C., Spirandelli, D., Franklin, E. C., Lynham, J., Kantar, M. B., Miles, W., . . . Hunter, C. L. (2018). Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions. *Nature Climate Change, 8*(12), 1062-+. doi:10.1038/s41558-018-0315-6

Ollerton, J., Winfree, R., & Tarrant, S. (2011). How many flowering plants are pollinated by animals? *Oikos, 120*(3), 321-326. doi:10.1111/j.1600-0706.2010.18644.x

Ozay, E., & Oztas, H. (2003). Secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education, 37*(2), 68-70. doi: 10.1080/00219266.2003.9655853

Palmer, P. I., & Smith, M. J. (2014). Model human adaptation to climate change. *Nature, 512*(7515), 365-366. doi:10.1038/512365a

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., & Kunin, W. E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology & Evolution, 25*(6), 345-353. doi:10.1016/j.tree.2010.01.007

R Core Team. (2019). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Retrieved from https://www.R-project.org

Scaven, V. L., & Rafferty, N. E. (2013). Physiological effects of climate warming on flowering plants and insect pollinators and potential consequences for their interactions. *Current Zoology, 59*(3), 418-426. doi:10.1093/czoolo/59.3.418

Schreiner, C., Henriksen, E. K., & Hansen, P. J. K. (2005). Climate Education: Empowering Today's Youth to Meet Tomorrow's Challenges. *Studies in Science Education, 41*(1), 3-49. doi:10.1080/03057260508560213

Sharp, J. G., & Kuerbis, P. (2006). Children's ideas about the solar system and the chaos in learning science. *Science Education, 90*(1), 124-147. doi:10.1002/sce.20126

UNFCCC. (1997). *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. Adopted at COP3 in Kyoto, Japan, on 11 December 1997

UN General Assembly. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. 21 October 2015, A/RES/70/1. Retrieved from https://www.refworld.org/docid/57b6e3e44.html

Wandersee, J. H. (1986). Plants or animals - which do junior high-school students prefer to study. *Journal of Research in Science Teaching, 23*(5), 415-426. doi:10.1002/tea.3660230504

Wandersee, J. H., & Schussler, E. E. (1999). Preventing plant blindness. *American Biology Teacher, 61*(2), 82-86. doi:10.2307/4450624

Woodcock, B. A., Isaac, N. J. B., Bullock, J. M., Roy, D. B., Garthwaite, D. G., Crowe, A., & Pywell, R. F. (2016). Impacts of neonicotinoid use on long-term population changes in wild bees in England. *Nature Communications, 7*. doi:10.1038/ncomms12459