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Using Mathematics to Know How to Teach Climate Change to Pre-Service Teachers: Is Knowledge Enough?

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ABSTRACT

Climate Change is one of the greatest challenges for humanity and education plays a fundamental role in raising awareness in society about the importance and need to take adaptation and mitigation measures. Climate Change can be treated from the point of view of education as a competence formed by three dimensions: knowledge, skills and attitudes. In this study we have looked to establish how these three parts are related among them, and if an increase in the part of knowledge also implies a change in skills and / or attitudes. To this purpose, 84 future pre-service teachers have received training focused only on the knowledge part about climate change: what it is and what its causes are. Through a survey carried out before and after the training, the value of each of the parts that make up the competition has been measured. The results show that a training focused on knowledge also improves the attitudinal part, but not the skills part. Therefore, if you want to achieve complete climate competence, it is not enough to teach knowledge, but it is also necessary to pay attention to skills during the formation. These results should be considered when designing the teaching on Climate Change, in order to optimize the resources and time available.

1. Introduction

Climate Change has been defined by the United Nations as the greatest global threat facing humanity. Scientific evidence shows an increase in the average temperature of our planet compared to the pre-industrial era, mainly caused by the increase in the concentration of greenhouse gases such as CO_2, emitted by human activity (Field & Barros, 2014).

During the last decades, the anthropogenic Climate Change has impacted natural and human systems on all continents and seas (Intergovernmental Panel on Climate Change [IPCC], 2014). The oceans are acidifying and increasing their temperature, the sea level is rising and there are more and more extreme weather events such as hurricanes, prolonged heat waves, floods or droughts. The retreat of glaciers and the melting of permafrost or ice in large regions such as

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the Arctic, Antarctica and Greenland are evidence of a rapid change in climatic conditions, the extent of which will depend on our ability to act globally (Pachauri et al., 2014).

Althougt the perception and awareness about Climate Change have risen in Europe and european citizens now identify climate change as the single most serious problem facing the world (European Union, 2021), different strategies needed to adapt and mitigate the effects of Climate Change may not be effective without the active involvement of society, as educated communities aware of the Climate Change risk are better prepared, more resilient, make better decisions, and are mobilized to face the enormous challenges of the climate crisis (UNESCO, 2009).

Therefore, there is a general consensus that indicates the importance of education in relation to Climate Change. International agencies such as the UN or UNESCO have declared the importance of education to improve the resilience of communities around the world (Buckler & Creech, 2014), and there are international initiatives that promote Education on Sustainability, highlighting the fact that the Sustainable Development Goals (SDG) propose an important role for Education in raising awareness about Climate Change. Specifically, the third objective of the 13th goal is to improve education, awareness and human and institutional capacity in matters of mitigation, adaptation, reduction of impacts and early warning of Climate Change. A better understanding of Climate Change has positive consequences, as more awareness of environmental issues and a deeper sense of responsibility (Anderson, 2012; Bain et al., 2016).

An educational approach involving not only public awareness campaigns but also a more formal educational responses is needed (Mochizuki & Bryan, 2015). Therefore, it is necessary to develop concrete strategies to bring Climate Change education to daily practice in the classroom. Some countries, such as Portugal and Italy have tried to introduce Climate Change in their study plans. But in Spain there is still no concrete and complete strategy to address this issue in regulated education.

Competency-based learning is used in most Organization for Economic Co-operation and Development, OECD, countries (OECD, 2019). It is a successful model because it promotes active learning, develops critical thinking and problem-solving skills, emphasizing skills for collaborative knowledge creation. Thus, the model is focused on students and its objective is to train critical citizens to make better and responsible decisions in our society. Based on this precept, it has been proposed an Educational Competence focused on Climate Change as a comprehensive and rapid approach, which serves to include and address Climate Change in a more efficient way (Ferrari et al., 2019; Fuertes et al., 2020).

The concept of competence is established as the ability to respond to complex demands and perform various tasks appropriately, involving a combination of practical skills, knowledge, motivation, ethical values, attitudes, emotions and other social and behavioral components that are mobilized together for effective action (Delors et al., 1997). Therefore, the concept of competence provides an ideal framework to develop understanding, awareness and skills related to Climate Change through education, fitting into the key competence framework recommended by the European Union (EU).

The Climate Change competence is based on this structure and on the compilation of scientific literature on the role of education in Climate Change. There is a large body of literature on proposals for how to include Climate Change in education, ranging from the role of science teaching and learning, to developing skills or raising awareness.

The competence is made up of three complementary subdimensions:

- Knowledge (learn to know).
- Skills (learn what can be done).
- Attitudes (learn to be).

The knowledge is based on evidence-based science and current scientific consensus. Scientific evidence must be used to understand what Climate Change is, its causes and consequences. In the dimension of skills, it is possible to connect the capacities that the student must acquire in the framework of mitigation and adaptation, which are the main strategies to face Climate Change, learning what can be done. But the fact that a person knows a problem and knows what can be done to avoid it, does not necessarily imply that that person does it and applies that knowledge. For example, a person can know what recycling is (knowledge) and know how to recycle (skill), but that does not necessarily imply that he or she is going to do it. Therefore, in the dimension of attitudes, the objective is to sensitize and mobilize society in the face of this important challenge.

Most educational interventions in regulated education are aimed at increasing knowledge (cognitive dimension), and the attitudinal part is sometimes treated in a transversal way. However, the urgency of a change in attitudes related to mitigation and adaptation to Climate Change, makes it necessary to change the way of being and doing, changing aspects such as consumption, transport or food habits.

The Climate Change competence should be useful for teachers to plan their classes and show the connections throughout the curriculum of this important issue. It could be included without major changes in legislation, in all countries where Competency-Based Learning is established. This could be a quick and easy route to implement the "Emergency Curriculum" outlined in the Paris Agreement on Climate Change, which is supposed to be implemented in all countries that signed the agreement (United Nations, 2016).

2. Objective and Methodology

In order to optimize resources and methodologies, research is still needed to be done on what is the best way to teach about climate change, especially about how to teach to future teachers and trainers, on whose future work the education of a large part of the population will depend.

The main objective of this research is to check mathematically the relationship between the knowledge part of Climate Competence and the other parts: skills and attitudes, looking for if knowledge, skills and attitudes are related in such a way that if one of them increases, the others will also increase. That is, if an increase in the part of knowledge also implies an improvement in skills and / or attitudes.

As an instrument to measure Climate Change Competence it has been designed a survey, based on the three dimensions mentioned above. It consists of a closed-ended 1- 4 Likert-scale questionnaire with 36 questions/items, each of them related with one part of the dimension. Items of each dimension are randomly distributed through the survey. Knowledge has been evaluated with 14 items, related with biophysical processes; causes; consequences; adaptation and mitigation. The skills dimension has been analysed with 9 items related with purchases, transport and energy savings. Finally, the attitude dimension included questions related with the trust per agent and sources of information, personal responsibility and education.

The questionnaire has been validated to ensure that each question generates useful information and that the questions within each of the three dimensions are actually correlated, which is important to understand the underlying structure of the Climate Change competition.

The methodology of this study consists in using a pre-experimental design without control group and with pre- and post-test measurements (Campbell & Stanley, 1973) of the Climate Change Competence of the participants of our sample.

The sample used for this study has been 84 university students on their 2nd year of Primary Education Teacher degree that are being trained to become generalist primary school teachers in Spain, not specialist science teachers.

Before receiving formation about climate change, the participants were required to answer the described survey, whose questionnaire consisted of questions related to each part of the Climate Change Competence: knowledge, skills and attitudes. The same survey has been answered by the same group twice, the first one (pre-test) before their formation about climate change and the other one, after it (post-test). As each question was related with one part of the Climate Change Competence, the analysis of the individual answers allows to individually position each of the participants in each of the pillars of the competence before and after their formation.

After the pre-test survey had been done, a formative session about Climate Change was carried out, focused only on one of the competence parts: the scientific knowledge about Climate Change: its causes and consequences, and no contents about skills and attitudes were worked. After this session, which was supposed to have increased knowledge about Climate Change, the survey has been passed again as a post-test.

The mathematical analysis of these results allows us to check if, as one of the parts of the competence increases, knowledge, the parts referring to skills and attitudes also increase, and in what way and with what depth.

These results may be taken into account when designing the specific training on Climate Change, since they will show whether it is necessary to devote more time and content to the part of skills and attitudes, or if it is enough to increase knowledge on the subject to achieve a change in attitude.

The evolution between the pre- and post-test was analysed through a descriptive exploration of the data (median, mean and standard deviation) using the statistical program Jamovi 2.00 (Jamovi Proyect, 2021). Afterwards, determination of normality data was carried out in order to determine the distribution of the criterion variables. Then, the nonparametric Wilcoxon test was applied, to test if there were significant improvements in Climate Change Competence parts between pre-test and post-test. In order to better interpret its value, effect size has been added using Cohen criteria, and in order to quantify the magnitude of the difference between two means, values between 0.10 and 0.29, are considered as small differences, 0.30 to 0.49 as moderate differences and values greater than 0.50 as large (Cohen, 1988).

3. Results and discussion

The pre-test and post-test survey has been answered by 84 pre-service teachers in Early Childhood and Primary Education at University of Salamanca (Spain).

It has been analyzed whether formation about climate change improves the dimensions of Climate Change Competence. It has been used the nonparametric Wilcoxon test, where the independent variable was formation about climate change and dependent variables were every one of the subdimensions (knowledge, skills and attitudes) of the Climate Change Competence. The results are summarized in table 1.

Table 1.
Comparative analysis between pre-test and post-test of C3 subdimensions

Dimension	Test	*N*	*M*	*Med*	*SD*	Hypothesis Testing		
						Z	WS-R *p*	*R-B c*
Knowledge	Pre	84	2.90	2.93	0.25	-2.52	.012	0.33
	Post	84	2.99	2.93	0.30			
Ability	Pre	84	2.88	2.89	0.34	-.634	.526	0.09
	Post	84	2.87	2.89	0.37			
Attitude	Pre	84	3.08	3.14	0.37	-3.16	.002	0.44
	Post	84	3.19	3.21	0.35			

Ele: elementary; Sec: secondary; n: sample size; Med: median; M: mean; SD: standard deviation; Z: Standardized Test Statistic; WS-R p: Wilcoxon Signed-Rank t-test; R-B c: effect size (Cohen criteria by Rank-Biserial Correlation)

A significant improvement in the knowledge and attitudes dimensions of Climate Change Competence was observed. The difference between the average scores of the pre- and post-test has a moderate effect size of 0.33 and 0.44 to knowledge and attitude respectively. These results indicate that there are significant differences between pre-test and post-test, being post-test the one that reaches a higher level in knowledge and attitude subdimensions. The skill subdimension does not present significant differences, as it is shown on figure 1.

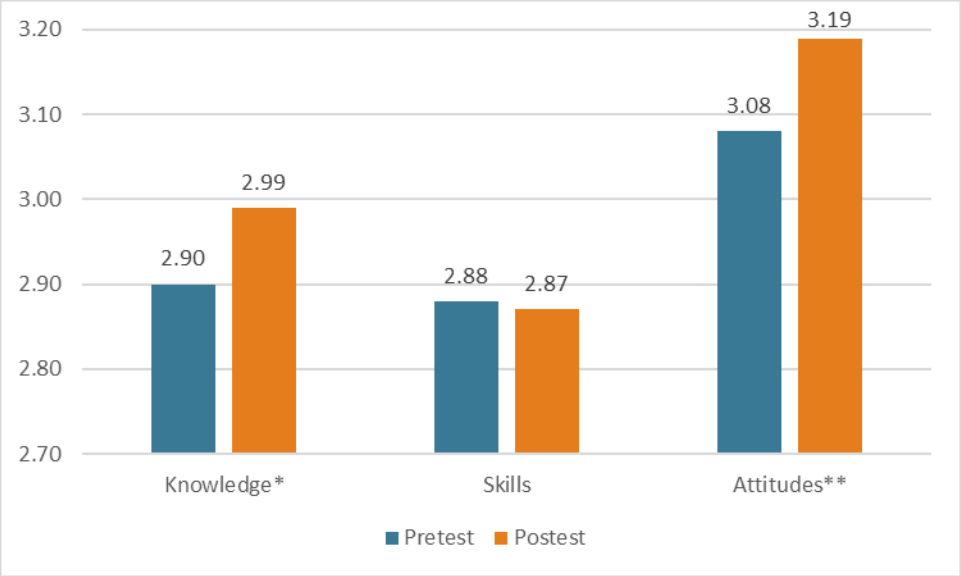

Figure 1. Comparative on sub-dimensions of C3 between social science and experimental science PSTs towards mean score. (*p < .05, **p < .01, *** p <. 001)

The results show a significative increase in the knowledge part of the Climate Change Competence, although not as great as would have been desirable, and perhaps because the participants had not been warned that they would again be asked about their knowledge, so they did not study the content as if it had been a regular exam.

The most important result is that, despite the fact that the course did not include content related to attitudes, the attitude of the future teachers increased significantly, showing that the increase in knowledge also implies a change in attitudes. However, the part corresponding to skills did not improve, remaining practically constant before and after the course, even showing a slight, non-significant decrease.

4. Conclusions

The results show that a course on Climate Change focused only on one of the competence parts: the scientific knowledge about Climate Change: its causes and consequences, can also improve the attitudes, but not the skills: learners do not know what they can do.

In conclusion, it should be noted that when teaching about Climate Change, in order to get the full competence, it is not enough to focus on the knowledge part. If we want learners to achieve the full climate competence, the skills part needs to be specifically addressed during the formation. As stated in the title of the study presented, the mathematical study of the responses has made it possible to establish the relationships between the parts of the climate competence, showing how mathematics is a necessary tool to understand how training on climate change should be conducted.

These results should be considered when designing formation about Climate Change, in order to optimize the resources and time available.

Supporting Information

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