Doctoral Program Education in the Knowledge Society

Implementation of MOOCs as a tool for improving Climate Change Competence In Pre-Service and In-service Elementary and Secondary school teachers

Ph.D., THESIS

Submitted by

Enzo Rainiero Ferrari Lagos

PhD Supervisors:
Prof. Camilo Ruiz Méndez
Prof. Fernando Martínez Abad

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Camilo Ruiz Méndez, Ph.D. in Physics and Professor in the Department of Didactics of Mathematics and Experimental Sciences at the Salamanca University, and Fernando Martínez Abad, Ph.D. in Education Sciences and Professor in the Department of Didactics, Organization and Research Methods at the Salamanca University.

CERTIFY:

That the work "Implementation of MOOCs as a tool for the improvement of Climate Competence for Primary, Secondary and Pre-services Teachers" has been developed by Enzo Rainiero Ferrari Lagos under their supervision in the Doctoral Programme Education in the Knowledge Society of the Salamanca University, as a Thesis Project to obtain the degree of Ph.D. in Education in the Knowledge Society at the Salamanca University.

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Prof. Camilo Ruiz Méndez

Prof. Fernando Martínez Abad

To God and my Family

"We must have perseverance and above all confidence in ourselves. We must believe that we are gifted for something and that this thing must be attained."

Marie Curie

"Try not to become a man of success, but rather try to become a man of value."

Albert Einstein

"I can do all things in him who strengtheneth me."

Philippians 4:13

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Resumen

La sociedad actual se enfrenta al desafío del Cambio Climático (CC). En este ámbito, la promoción del Desarrollo Sostenible ha obtenido un amplio reconocimiento internacional como el camino a seguir para mitigar sus consecuencias.

La ONU, a través de los Objetivos de Desarrollo Sostenible, tiene como propósito sensibilizar, educar y elaborar estrategias de acción para hacer frente a este problema global. Lograr estos objetivos implica la necesidad de establecer marcos de acción que faciliten una Educación para la participación, la concienciación y la formación crítica y responsable de la ciudadanía. Así surge la Educación del Cambio Climático, una manera estratégica y significativa de promover los principios y prácticas del Desarrollo Sostenible.

A pesar de que la educación está siendo reconocida como una herramienta fundamental en la lucha contra el CC, aún no existe una estrategia clara para implementarla de manera efectiva. Por ello, la utilidad de esta investigación radica en la introducción del concepto de **Competencia en Cambio Climático (C3)**, que tiene como objetivo desarrollar ciudadanos con una conciencia sólida sobre este problema a través de la construcción, aplicación y difusión de conocimientos, comportamientos y valores.

Los elementos que forman parte de la **C3** son:

- **Aprender a saber**: incluye conocimientos y contenidos como la física y química del CC, y cómo los científicos explican causas y consecuencias.
- **Aprender a hacer**: desarrolla las habilidades de adaptación y mitigación.
- **Aprender a ser:** busca soluciones ambientales a través de actitudes y decisiones, con juicio y responsabilidad.

Para desarrollar esta competencia es necesario acercar la ciencia del CC a la comunidad educativa. Una excelente alternativa, es realizarla a través de las nuevas herramientas formativas como los cursos en línea masivos y abiertos (MOOC). El presente trabajo se realizó mediante el diseño pre-experimental pretest-postest de un solo grupo, donde se evaluó la mejora de la **C3** en profesores de educación primaria y secundaria. También se evaluó en distintas poblaciones mediante dos de los tres MOOCs diseñados y creados para estas poblaciones. Estos cursos fueron "Concienciación y capacitación en materia de CC para profesores de Primaria y Secundaria" y "Ciencia de Cambio Climático." El comportamiento de la C3 se analizó a través de las técnicas de análisis de datos multivariante. Los resultados demostraron que los estudiantes que participaron en

la formación de este curso mejoraron en los elementos de la C3. Además, los docentes afirmaron que tras completar la actividad de formación se sienten más seguros y comprometidos con la enseñanza de la CC. Por lo tanto, se refuerza la idea de que es necesario crear y diseñar más actividades de formación para los profesores y público en general. Esta investigación es el comienzo del desarrollo de la C3 en el personal educativo, pues se espera que futuras investigaciones desarrollen esta competencia en los estudiantes y sociedad en general.

Abstract

Today's society is facing the challenge of Climate Change (CC). In this area, the promotion of Sustainable Development has achieved wide international recognition as the way forward to mitigate its consequences.

Through the Sustainable Development Goals, the UN aims to increase awareness, provide education, and develop action strategies to tackle this global problem. To achieve these objectives implies the need to establish action frameworks that allow education for participation, awareness, and critical and responsible training of citizens. Thus arises Climate Change Education, a strategic and meaningful way to promote the principles and practices of Sustainable Development.

Although education is being recognized as a fundamental tool to address CC, there is still no clear strategy to implement it effectively. Therefore, the usefulness of this research lies in the introduction of the concept of Climate Change Competence (C3), which aims to develop citizens with a solid awareness of this problem through the acquisition, application, and diffusion of knowledge, behaviors, and values.

The elements that are part of C3 are:

- **Learning to know**: includes knowledge and content such as the physics and chemistry of CC and how scientists explain causes and consequences.
- **Learning to do**: develops adaptation and mitigation skills.
- **Learning to be**: willingness to execute actions that help find environmental solutions through attitudes and decisions, with judgment and responsibility.

To develop C3, it is necessary to bring the science of CC closer to the educational community. An excellent alternative is to do it through new training tools such as massive open online courses (MOOC). The present work was carried out through a pre-experimental pretest-posttest design of a single group, where the improvement of C3 in elementary and secondary education teachers was evaluated. It was also evaluated in different populations using two of the three MOOCs designed and created. These courses were "CC Awareness and Training for Primary and Secondary Teachers" and "Climate Change Science." C3 behavior was analyzed through multivariate data analysis techniques. The results showed that students who participated in this course training improved in the elements of C3. In addition, teachers stated that they feel more confident and committed to teaching CC after completing the training activity. Therefore, it reinforces the idea that there is a need to create and design more training activities for teachers and

the general public. This research is the beginning of the development of C3 in educational personnel, as future research is expected to develop this competence in students and society in general.

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List of abbreviations and acronyms

A&M	Adaptation and Mitigation
AAAS	American Association for the Advancement of Science
AC	Action competence
AGFI	Adjusted Goodness of Fit Index
AIC	Akaike Information Criteria
BID	Inter-American Development Bank
BPP	Biophysical Processes
C3	Climate Change Competence
CAU	Causes
CC	Climate Change
CCE	Climate Change Education
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CFIE	Center for Training and Educational Innovation of Castilla y Leon
CO_2	Carbon dioxide
CSIC	Spanish National Research Council
CSQ	Consequences
DESD	Decade of Education for Sustainable Development
DWLS	Diagonally Weighted Least Squares
EC	Environmental competence
ECV	explained common variance
ECVI	Expected Cross Validation Index
EDS	Education for Sustainable Development
EDU	Educational support
EFA	Exploratory Factor Analysis
EMC3	Education, Mathematics, Science and Climate Change
ESA	European Space Agency
ESA	Energy Saving
GCED	Global Citizenship Education
GFI	Goodness of Fit Index

GHE	greenhouse effect
GHGs	greenhouse gases
INTEF	National Institute of Educational Technologies and Teacher Training
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ISTs	in-service teachers
MOOCs	Massive Open Online Courses
NASA	National Aeronautics and Space Administration
NCSE	National Center for Science Education
NEP	New Environmental Paradigm
NFI	Normalized Fit Index
NJSLS	New Jersey Student Learning Standards
NOAA	National Oceanic and Atmospheric Administration
OECC	Spanish Climate Change Office
OECD	Organization for Economic Co-operation and Development
PEC	Pro-Environmental competence
ppm	parts per million
PSTs	pre-services teachers
PUC	uncontaminated correlations
PUR	Purchases
RAE	Royal Spanish Academy.
REDD+	reducing emissions from deforestation and forest degradation
RES	Responsibility
RMSEA	root mean square residual of approximation
RPSs	Role-play simulations
SDGs	Sustainable Development Goals
SEM	Structural Equation Modelling
SEO Birdlife	SEO Birdlife - Sociedad Española de Ornitología
SL	Schmid-Leiman
SRMR	standardized root means square residual
STEM	Science, Technology, Engineering and Mathematics
TLI	Taker-Lewis Index

TRA	Transport
TRU	Trust per Agent
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Program`s
UNFCCC	United Nations Framework Convention on Climate Change
USAL	Salamanca University
USGCRP	United States Global Change Research Program
VIF	variance inflation factors
WGs	working groups
WLS	Weighted Least Squares
WWF	World Wildlife Fund

Chapter 0

Introducción

0.1 Resumen ampliado

0. Capítulo 0. Introducción

0.1 Resumen ampliado

El cambio climático (CC) es la mayor amenaza a la que se enfrentan la civilización y todas las especies que viven en la Tierra (IPCC, 2014a). Científicos de todo el mundo han observado que nunca antes en la historia de la Tierra se había producido un cambio climático tan rápido como el que se ha vivido desde la Revolución Industrial, un cambio sobre los sistemas naturales en el que ha influido el hombre.

Para afrontar este reto es necesario movilizar a la sociedad dentro de un calendario trazado por la Convención Marco de las Naciones Unidas sobre el Cambio Climático a través del Acuerdo de París, cuyo objetivo es la descarbonización total de la economía para el año 2050. Este acuerdo requerirá de la toma de importantes acciones por parte de los gobiernos, de las industrias y de aquellas personas comprometidas con el planeta (Naciones Unidas, 2015).

Cada vez se considera más relevante el papel de la educación para hacer frente a los retos del cambio climático (Quarderer et al., 2021; Arto-Blanco et al., 2017, Le Blanc, 2015; Mochizuki & Bryan, 2015; Buckler & Creech, 2014). El Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC), creado por la ONU, institución de la que forman parte 195 naciones, es una organización que informa sobre la ciencia del CC además de la política de mitigación y adaptación. El IPCC ha reconocido por primera vez, de forma explícita, la relevancia de incorporar la educación dentro de las herramientas estratégicas para abordar el CC en las perspectivas de adaptación y mitigación (IPCC, 2014).

Paralelamente, varios acuerdos y tratados mundiales reconocen que el apoyo educativo es esencial en los esfuerzos para abordar el CC. El Acuerdo de París de la CMNUCC reconoce que la educación es fundamental para movilizar a la sociedad contra el cambio climático. Afirma que la creación y aplicación de nuevas estrategias en materia de educación y sensibilización son necesarias para mantener a la población informada. La UNESCO, a través de la Educación para el Desarrollo Sostenible (EDS), pretende dotar a jóvenes y niños de los conocimientos, habilidades y actitudes necesarias para tomar decisiones informadas y realizar así acciones responsables en pro de la integridad ambiental, la viabilidad económica y una sociedad justa. Para ello fomenta la creación de estrategias que proporcionan a los educadores las competencias necesarias para

empoderar y movilizar a esos jóvenes. Los Objetivos de Desarrollo Sostenible (ODS) señalan que la educación es fundamental para afrontar retos globales como el CC. Por lo tanto, es necesario fortalecerla para generar acciones contra este fenómeno.

Existe un gran número de programas internacionales, nacionales y locales para abordar la cuestión de la educación y el CC, pero los esfuerzos son todavía pequeños en comparación con la escala del desafío al que nos enfrentamos. Por ello, sigue siendo necesaria la creación de un recurso estratégico eficaz para la mitigación y adaptación al cambio climático (Ruiz & Ferrari, 2019).

Hay muchos ejemplos que describen la necesidad de crear y aplicar una estrategia eficaz para llevar el CC a la Educación, pero las partes responsables de la educación en muchos países aún no han desarrollado un marco coherente para la educación sobre el cambio climático (Mochizuki y Bryan, 2015) y, aunque ha habido esfuerzos como la inclusión en el currículo de contenidos sobre el cambio climático en la educación primaria y secundaria, la cantidad de tiempo dedicada a la enseñanza del CC sigue siendo mínima (Reid et al., 2016). Lamentablemente, el CC sigue siendo ignorado por las asignaturas sociales y científicas porque la mayoría de estos programas educativos no relacionan el cambio climático con estas disciplinas (Reid, 2019). Incluso si se enseñan contenidos científicos sobre el CC, no se relacionan con otras disciplinas como la economía, la política u otras ciencias humanas y sociales (Herman et al., 2017), olvidando tratar el CC como un problema socio-científico (Helen 2016).

Otra posible justificación que podría explicar la ausencia del CC en el currículo es la complejidad del tema. Por ejemplo, muchos profesores afirman que les resulta difícil enseñar el CC porque no se les enseñó durante su proceso de formación docente (Quarderer et al., 2021; Boon, 2016). Además, en la mayoría de los programas de formación docente, la enseñanza de contenidos sobre medio ambiente y CC no es obligatoria (Hestness et al., 2011). Incluso algunos profesores de pre-servicio de ciencias (PSTs) declararon que no encuentran contenidos de CC en sus planes de estudio (Seroussi et al., 2019). Otra investigación mostró que sólo el 4% de las diferentes universidades en España tienen CC en sus planes de estudio (Sureda-Negre et al., 2014).

Por ello, a pesar de que el CC forma parte del currículo de primaria y secundaria, los profesores a veces no lo imparten o no lo hacen adecuadamente porque es una asignatura que no dominan suficientemente. Varios estudios explican que la ciencia que hay detrás de este fenómeno es difícil de entender (Oversby, 2015) y hay muchas ideas erróneas sobre los PSsT (Liu et al.,

2015) y de los profesores en servicio (IST) (Dawson, 2012). Por ejemplo, algunos estudios apuntan a conceptos erróneos o deficiencias conceptuales en la ciencia del CC. Según Herman et al. (2017), los ISTs y (Nyarko & Petcovic, 2021) los PSTs creen que el agujero en la capa de ozono es una causa del CC y que produce una gran radiación en la atmósfera. Esta creencia también se observó en estudiantes de secundaria (Bello Benavides et al., 2017) y universitarios (Gutiérrez-Pérez, 2015; Meira-Cartea et al., 2018). Otro ejemplo de desconocimiento de la ciencia CC en los profesores es la dificultad para distinguir entre conceptos tan simples como el calentamiento global y el efecto invernadero (Arslan et al., 2012). Según Wise (2010) los PSI no pueden diferenciar entre clima y tiempo atmosférico. El desconocimiento de las causas del CC es también otra cuestión importante. Según Hestness et al. (2014) los ISTs creen que los humanos no tienen la culpa del CC. Como ejemplo, uno de cada cinco TSI en Estados Unidos cree que el CC se debe a causas naturales (Plutzer y Hannah, 2018) y otros TSP incluso niegan la existencia del CC (Higde et al., 2017). Además, los conceptos erróneos se presentan en cuestiones relacionadas con los comportamientos y las capacidades de mitigación. Por ejemplo, según (Ikonomidis et al., 2012) la mayoría de los TSP creen que cualquier acción ecológica puede contribuir a mitigar el CC. Actividades como el reciclaje y la limpieza de las playas se identifican como acciones potenciales para abordar el CC y consumir menos, usar energía nuclear y ahorrar energía, se consideran acciones débiles. La mayoría de las TSI desconocen las acciones para remediar las consecuencias del CC (McNeal et al., 2014).

Las actitudes son otro elemento importante que puede explicar los déficits de CC en la educación. Lamentablemente, todavía hay muchos ISTs que muestran un bajo nivel de voluntad para adoptar acciones que aborden el CC (Ambusaidi et al., 2012). Según Karami et al. (2017), la mayoría de las ISTs en Irán presentan un bajo nivel de Actitud en CC, incluso menor al conocimiento. Otro elemento asociado a las actitudes es la desconfianza en los medios de comunicación sobre el CC, que, según Helen (2016), es una de las principales barreras que influye en el bajo conocimiento de los PSTs sobre las causas, consecuencias y acciones para abordar el CC. Según Ferrari-Lagos et al. (2021) la mayoría de los profesores desconocen fuentes como el IPCC o la NOAA.

Otros estudios sostienen que la enseñanza del CC presenta problemas porque su contenido es interdisciplinario (Hugé et al., 2017) y hay investigadores que afirman que muchos profesores consideran los contenidos sobre el CC como controvertidos (Seow y Ho, 2016). Como se ha visto anteriormente, esto trae un gran problema porque, una vez que los profesores se colocan en el

sistema educativo, carecen de conocimientos sobre la ciencia de este fenómeno, las causas, las consecuencias, las acciones para su mitigación y las estrategias para su enseñanza y sensibilización (Seroussi et al., 2019). Debido a ello los docentes tienen el desafío de estudiar este fenómeno por su cuenta y muchas veces se encuentran con afirmaciones basadas en datos inciertos y parciales que desafían la realidad real del problema (Ruiz & Ferrari, 2019).

Este proyecto de tesis nace de la necesidad de crear soluciones para los problemas descritos anteriormente a través de una estrategia que permita trabajar en los conocimientos, habilidades y actitudes en torno a la ciencia del CC en los PSTs e ISTs, así como la correcta implementación de los contenidos y la didáctica del CC en las instituciones de formación docente y el sistema educativo en general. Nuestra principal propuesta consiste en la introducción de una competencia que llamaremos Competencia en Cambio Climático (C3). Esta servirá como herramienta para implementar varios aspectos relacionados con el CC propuestos en tratados y marcos internacionales como el Acuerdo de París, la EDS y los ODS, que abordan cuestiones importantes como la sostenibilidad y muchos otros retos globales importantes.

No obstante, el CC se diferencia de otros estos temas por su urgencia (Gutiérrez-Pérez et al., 2020). Por lo tanto, decidimos proponer la C3 como una estrategia basada en conceptos educativos. Esta competencia permitirá la introducción de las contribuciones más actuales de la literatura en la educación sobre el cambio climático (ECC), así como la última y mejor ciencia disponible sobre el cambio climático, incluyendo los también relevantes marcos institucionales mencionados anteriormente.

En esta competencia (C3) hay tres dimensiones principales. La primera, denominada aprender a aprender, explica la ciencia que hay detrás de este fenómeno, la complejidad del problema del CC y el impacto de la actividad humana como principal causa, así como los futuros escenarios que deberemos enfrentar de no descarbonizar la economía para el año 2050.

El segundo elemento es aprender a hacer, donde se desarrollan acciones personales y colectivas para afrontar este fenómeno, buscando soluciones a nivel individual y colectivo. Finalmente, el último elemento es aprender a ser y estar. Esta dimensión desarrolla el conocimiento en acción a través de actitudes y acciones. Esto incluye valores importantes como el reconocimiento de que se trata de un problema global que requiere esfuerzos individuales, locales, nacionales e internacionales, así como la aprehensión de que nuestros esfuerzos son significativos

junto con la aceptación de políticas públicas y el pensamiento crítico sobre este fenómeno y sus consecuencias.

El concepto de C3 es útil para recoger y organizar todo el conocimiento y las aportaciones en torno al CCE, pero también es útil para diseñar nuevos materiales, estrategias e intervenciones educativas para mejorar el C3. Entre las muchas estrategias y actividades educativas que se pueden realizar en torno al C3, en esta tesis se investiga el efecto de actividades formativas como la de los Cursos Online Masivos y Abiertos (MOOC).

Son varios los elementos que han hecho de los MOOCs una herramienta importante y eficaz para avanzar en la C3. Se ha demostrado que estas herramientas de aprendizaje pueden aumentar la alfabetización climática de los ciudadanos (Burch & Harris, 2014; Ferrari et al., 2019; Otto et al., 2019). Por ello, lo proponemos como una alternativa para mejorar los elementos de la C3 en los ciudadanos. Para tal fin, hemos creado y diseñado un MOOC para implementarla entre los profesores, ofreciéndoles la mejor ciencia disponible proporcionada por los científicos a través de los informes del IPCC, la pedagogía y las diferentes metodologías de enseñanza.

En el desarrollo de esta tesis se han creado hasta ahora tres versiones diferentes de MOOCs. Estos se han distribuido en tres plataformas diferentes: MiriadaX, Centro de Formación del Profesorado e Innovación Educativa de Castilla y León (CFIE) e Instituto Nacional de Tecnologías Educativas y Formación del Profesorado (INTEF). Las tres modalidades se caracterizan por una estructura sencilla diseñada para responder a las siguientes cuestiones: ¿Qué es el CC?, ¿Qué causa el CC?, ¿Cuáles son las consecuencias si no actuamos?, y ¿Qué podemos hacer desde la educación? Estas preguntas se responden en seis módulos. En esta tesis presentamos los resultados de dos de las tres versiones desarrolladas. En ellas, evaluamos el rendimiento de los profesores e identificamos los grupos con mejor rendimiento, así como la mejora del C3 al final del MOOC.

Por otro lado, este proyecto contribuye a ampliar la necesidad de crear programas de formación como éste, que, al ofrecerse de forma abierta, pretende llegar al máximo número de profesores. Con ello, esperamos contribuir a la formación de niños y jóvenes para que se conviertan en líderes de la sostenibilidad a través de la educación, la movilización y la concienciación con la intención de afrontar los retos del cambio climático.

Una vez que hemos introducido el contexto, la motivación y la definición del C3, además de la evaluación de la C3-Q, describimos los principales resultados de la tesis y esbozamos cómo están organizados todos estos resultados.

Los resultados se agrupan en dos partes principales. En primer lugar, se evalúa el C3 en grupos y se muestran las características que se han desarrollado para esta tesis. En la segunda parte, presentamos los resultados sobre el efecto de una intervención educativa en el C3.

Estos resultados se organizan a través de los trabajos que se presentan en los siguientes capítulos. En esta sección se presenta un resumen y se destacan los resultados para ofrecer una visión unificada de nuestros hallazgos del C3.

En el capítulo I describimos las razones que motivaron la realización de este proyecto de tesis. Como sabemos, la crisis climática requiere grandes esfuerzos, y la educación debe ser una de las herramientas clave para la mitigación y la adaptación. Sin embargo, no hay una estrategia concreta de cómo introducir el CC en la educación. Además, los profesores en formación y los profesores activos presentan muchas deficiencias en temas relacionados con este fenómeno y su ciencia y didáctica. Muchos profesores no están motivados para enseñar o tienen problemas para hacerlo. Estos son solo algunos de los inconvenientes que encontramos en la literatura. Por lo que esta tesis, proponemos algunas alternativas para tratar de resolverlas.

El capítulo II establece la competencia sobre el cambio climático (C3) como estrategia educativa para introducir este fenómeno en la enseñanza. Para ello se identificaron los conocimientos, habilidades y actitudes sobre el CC que deben tener los profesores en formación (PSTs) y profesores en servicio (ISTs) de primaria y secundaria. Entre los conocimientos sobre el CC deben incluirse la comprensión del fenómeno, sus causas, consecuencias y medidas generales de adaptación y mitigación a este fenómeno. En cuanto a las habilidades, éstas incluyen una serie de acciones personales que ejecutamos desde nuestro hogar o trabajo y acciones asociadas a la forma en que nos movilizamos. Por último, las actitudes incluyen el papel fundamental de la educación como herramienta para afrontar este fenómeno. Además, los tratados internacionales (Tratado de París) y regionales como en la Unión Europea (establecimiento de las ocho competencias clave para el aprendizaje permanente), han determinado que es responsabilidad de todos luchar contra este fenómeno. Para desarrollar los elementos del C3 en los profesores y público en general, se propusieron los MOOC. Estas herramientas de aprendizaje presentan varias

ventajas, como el alcance global, el acceso gratuito y la creación de un clima motivador con personas con un interés común.

El capítulo III está dedicado a la validación de un instrumento para evaluar el C3 en el público en general, en profesores y en estudiantes.

Una vez hecho esto, hemos proporcionado el contexto, la motivación y la necesidad de crear una competencia. Iniciamos, por tanto, el proceso de definición formal del C3. Se realizó un análisis de contenido a partir de los informes del IPCC (2014), del ODS (2015) y del Acuerdo de París (2016) y una exhaustiva revisión bibliográfica, que sirvió para identificar los elementos que debe incluir esta competencia. Además, incluimos las opiniones de diferentes especialistas en la ciencia del CC y CAC, PSTs e ISTs que fueron recogidas durante una serie de seminarios desarrollados en la Universidad de Salamanca. Esto nos permitió elaborar un instrumento revisado por ocho profesores de Educación de la Universidad de Salamanca. Ellos forman parte del equipo de investigación Matemáticas, Educación, Ciencia y Cambio Climático (EMC3). Posteriormente, se realizó un estudio piloto, seleccionando los ítems que formarían parte del C3 y elaborando nuestro modelo teórico. Tras el análisis de contenido, la recopilación de opiniones de los agentes líderes, el juicio de expertos y el estudio piloto, se aplicó finalmente el instrumento para su validación. Los resultados de este proceso se muestran en el capítulo III. El cuestionario se aplicó a 530 participantes de la segunda edición del MOOC "Sensibilización y formación sobre el cambio climático para profesores de primaria y secundaria". Dado que el constructo es nuevo y se desconocía su estructura, se aplicó un análisis factorial exploratorio (AFE). Este reveló una estructura inicial de tres escalas independientes, conocidas como dimensiones, que consistían en conocimientos (procesos biofísicos, causas, consecuencias, adaptación y mitigación), habilidades (compras, transporte y ahorro de energía) y, por último, actitudes (responsabilidad de actuar, confianza en la fuente de información y apoyo a la educación). Una vez que se demostró que el C3 podía medirse como un constructo, se probó mediante un análisis factorial confirmatorio (AFC). En el AFC se evaluaron cuatro modelos (unidimensional, multidimensional, de segundo orden y bifactorial). El modelo bifactorial mostró los mejores índices en las tres escalas. Por lo tanto, el instrumento para determinar el C3 se denominará C3-Q

Estos resultados esenciales nos permitieron comprender que el C3 es un constructo que podría ser analizado a través de sus dimensiones y, más específicamente, a través de sus subdimensiones. Además, el C3-Q podría considerarse una herramienta valiosa para evaluarlo en individuos y grupos.

Los primeros resultados del C3 se presentan en el **capítulo IV**. Hemos analizado el C3 para determinar el tipo de relación entre los elementos de la competencia. Para ello, hemos dividido el estudio en tres partes.

En primer lugar, para determinar cómo se relacionan entre sí los conocimientos, las habilidades y las actitudes de la C3, aplicamos un análisis de correlación. El resultado obtenido fue que los conocimientos de C3 tienen una correlación positiva moderada con las habilidades y actitudes de C3.

En segundo lugar, entendiendo que las dimensiones del C3 presentan correlaciones positivas entre sí, examinamos el impacto de los conocimientos sobre las habilidades y si las actitudes median entre ellas. Para ello, se realizaron una serie de análisis de regresión. El resultado mostró que los conocimientos predecían positivamente las habilidades. Además, los resultados revelaron que las actitudes median significativamente la relación entre los conocimientos y las capacidades.

En tercer lugar, se examinó la relación entre los conocimientos y las actitudes y se determinó si las habilidades eran una variable moderadora en esta relación. Para ello, se llevó a cabo un análisis de regresión múltiple. Los análisis de pendiente simple revelan una actitud predicha positivamente cuando los niveles de habilidad son bajos, medios o altos. Así, el análisis sugiere que los individuos que realizan muchas actividades relacionadas con la mitigación del CC (tienen niveles altos en la dimensión de habilidad) son más propensos a crear conciencia para actuar contra el CC, incluso cuando el nivel de conocimiento científico sobre el CC es bajo.

En resumen, los resultados indican que es más probable que los conocimientos en CC proporcionen capacidad y actitudes en CC. Además, los resultados proporcionan algunas pruebas de que las personas que tienen conocimientos científicos sobre la ciencia del CC son más propensas a realizar actividades relacionadas con la mitigación del CC porque tienden a crear una conciencia para actuar contra el CC con creciente autonomía, juicio y responsabilidad personal. Finalmente, los resultados explican que la habilidad en CC refuerza la relación entre este conocimiento y las actitudes del C3.

Estos son hallazgos importantes que demuestran empíricamente que las dimensiones de la competencia no son independientes. La definición del C3 y los instrumentos de evaluación nos permiten mostrar estas correlaciones, que pueden ser útiles para diseñar nuevas intervenciones educativas o identificar el origen de los déficits en el C3 y actuar en consecuencia. Esto también significa que el avance de unas dimensiones puede afectar positivamente a las otras y establecer algunas prioridades para diseñar planes de estudio o nuevos materiales.

En **el capítulo V**, hemos evaluado la C3 en profesores de primaria y secundaria en formación (PSTs) de la USAL y en servicio (ISTs) de Castilla y León. En este caso, se aplicó a ambos el C3-Q (nuestro instrumento para evaluar el C3) elaborado en el capítulo III. El objetivo principal de este capítulo es observar si existen diferencias en los elementos de la C3 en los PST y en los ISTs según el nivel (primaria y secundaria) y el área (ciencias experimentales y ciencias sociales) de enseñanza. Para lograr este propósito, el análisis de este capítulo se dividió de la siguiente manera:

En primer lugar, comparamos los niveles de conocimientos, habilidades y actitudes de C3 en los PSTs e ISTs según el nivel de enseñanza. Utilizamos una U de Mann-Whitney no paramétrica. Los resultados revelaron que los conocimientos de los PSTs e ISTs de secundaria sobre los procesos biofísicos (BPP) y las consecuencias (CSQ) eran significativamente mayores que los PSTs e ISTs de primaria. Además, la subdimensión A&M fue significativamente mayor en los PSTs de secundaria. Por lo tanto, los resultados anteriores indican que los PSTs y los ISTs de secundaria son más propensos a comprender la ciencia del CC, concretamente la PBB y el CSQ. En cuanto a la dimensión de habilidad, el transporte fue la única subdimensión significativamente más alta en los PSTs de secundaria y en los ISTs. La subdimensión de compras presentó una puntuación significativamente mayor en los PSTs de secundaria. Por lo tanto, los PSTs de secundaria y los ISTs son más propensos a realizar acciones personales en su vida diaria relacionadas con el uso del transporte, como compartir el coche, utilizar el transporte público y caminar. Además, los PSTs de secundaria son más propensos a consumir productos locales y sostenibles. En cuanto a la actitud, no hubo diferencias significativas.

En segundo lugar, para comparar los elementos del C3 en los PSTs y los ISTs según su área de conocimiento, utilizamos también una prueba no paramétrica U de Mann-Whitney. En cuanto a los conocimientos, los PSTs e ISTs con formación en ciencias experimentales obtuvieron puntuaciones más altas que los PSTs e ISTs de ciencias sociales en las subdimensiones del BPP y del CSQ. Por lo tanto, nuestros resultados sugieren que los PSTs e ISTs de ciencias experimentales dominan mejor los conocimientos de la ciencia del CC. En la dimensión de habilidad, la subdimensión de transporte fue la que presentó diferencias significativas; los PSTs e ISTs con formación en ciencias sociales mostraron puntuaciones más altas que los PSTs e ISTs con formación en ciencias experimentales. Por lo tanto, los PSTs e ISTs con formación en ciencias sociales son más propensos a caminar, compartir el coche o tomar el autobús para desplazarse. En cuanto a las actitudes, la confianza en las fuentes de información y el apoyo a la educación fueron subdimensiones en las que los PSTs y los IST formados en la escuela de ciencias sociales puntuaron

más alto que los PSTs y los ISTs formados en la escuela de ciencias experimentales; sin embargo, las diferencias no fueron significativas.

En tercer lugar, comparamos si había una diferencia significativa en la confianza en los agentes de la información sobre el CC. Aplicamos un ANOVA de Friedmann a cada fuente de información (científicos, profesores, grupos ecologistas, medios de comunicación y Naciones Unidas). Los resultados sugieren que para los PSTs e IST los medios de comunicación son el grupo que presenta mayor desconfianza a la hora de informar sobre CC. Por el contrario, los científicos son el grupo con la clasificación media más alta en comparación con los demás.

En general, este capítulo sugiere que los PSTs y los ISTs primarios tienen poco conocimiento de la ciencia del CC, lo que conduce a un menor compromiso con las actividades del CC. Por lo tanto, es necesario acercar la ciencia a los PSTs de primaria mediante actividades prácticas. Los ISTs de primaria podrían aprender más sobre la ciencia de este fenómeno utilizando cursos en línea como los MOOC para avanzar a su propio ritmo. Además, este capítulo también reconoce que el conocimiento de la ciencia del CC por sí solo es ineficaz si no se relaciona con la parte social. Por lo tanto, para movilizar a la sociedad a la acción, necesitamos estudiar este fenómeno con todos los elementos del C3 (conocimientos, habilidades y actitudes) desde la perspectiva social y científica. Los PSTs y los ISTs con formación en ciencias experimentales deben entender que el CC es también un problema humano y que es imposible abordarlo sólo con ciencia y tecnología. Además, es esencial enseñar la ciencia del CC a partir de fuentes científicas, ya que éste es el grupo más creíble para informar sobre cuestiones relacionadas con este fenómeno.

Los resultados críticos de este capítulo demuestran que podemos medir el nivel de competencia entre distintos grupos e identificar el origen de esas diferencias. Este hallazgo significativo demuestra el poder del C3 y las herramientas de evaluación para crear diagnósticos sofisticados sobre el nivel actual del C3 y los factores que pueden explicar las diferencias significativas entre cada grupo.

Por último, en **el capítulo VI**, mostramos si es posible aumentar el C3 a través de los MOOC. Para ello, dividimos este capítulo en dos estudios basados en los cursos ofrecidos a los profesores.

El primer estudio muestra los resultados de la segunda edición del curso "Sensibilización y formación sobre el cambio climático para profesores de primaria y secundaria" desarrollado en la plataforma MiriadaX.

El segundo estudio presenta los resultados de la primera y segunda edición del curso "Ciencia del cambio climático" ofrecido en la plataforma del Centro de Formación del Profesorado e Innovación Educativa (CFIE) de Castilla y León.

En ambos estudios se aplicó el C3-Q elaborado en el capítulo III mediante un diseño preexperimental, con mediciones pre y post-test. Se utilizó la prueba t no paramétrica U de Mann-Whitney porque había muerte experimental y las respuestas a los cuestionarios eran anónimas. No pudimos emparejar las respuestas del pre y el post-test. La variable independiente fue el MOOC, y las variables dependientes fueron cada una de las subdimensiones del C3. Ambas secciones pretendían evaluar si había un aumento en los niveles de C3 de los participantes hacia el MOOC.

En el primer estudio, el análisis se dividió como sigue:

La primera parte está dedicada a evaluar si nuestro MOOC mejora las dimensiones del C3. En la dimensión de conocimiento, todas las subdimensiones presentaron una mejora después del curso. Esto explica que los participantes mejoraron su comprensión de los conceptos básicos de BPP, CAU, CSQ y A&M en CC. Asimismo, la dimensión habilidad presentó una mejora en todas sus subdimensiones. Los resultados revelan que los estudiantes aumentaron sus acciones frente al CC después de realizar el curso. En cuanto a las actitudes, las subdimensiones que mostraron mejoras fueron la confianza y el apoyo educativo. Sin embargo, la responsabilidad no mostró mejoras significativas.

En la segunda parte, comparamos la mejora de C3 a lo largo del curso en profesores y no profesores. En cuanto a los conocimientos, ambos grupos mostraron mejoras; esto explica que el curso aumentó la comprensión del CC. Sin embargo, en las dimensiones de habilidades y actitudes, sólo los profesores mostraron una mejora significativa. Los resultados revelan que los profesores son más propensos a mejorar sus acciones para combatir el CC y sus actitudes después del curso.

En la tercera parte, comparamos la mejora de C3 a lo largo del curso en españoles y latinoamericanos. Los resultados sugieren que ambos grupos aumentan el C3 en todas las dimensiones. Sin embargo, los niveles de habilidad y actitudes eran más altos para los participantes latinoamericanos antes de comenzar el curso. Así, los resultados indican que los latinoamericanos son más propensos a actuar contra el CC y tienen mejores actitudes hacia este fenómeno.

En la cuarta parte, comparamos la dimensión de habilidad por grupos de edad. Utilizamos una prueba no paramétrica de Kruskal Wallis. Los resultados revelaron que la dimensión de habilidad tiende a disminuir con la edad. Sin embargo, esta tendencia cambió para el grupo de 65 años o más. Las puntuaciones en habilidad fueron más altas en el grupo de 65 o más años que en el de 35 a 49 y 50 a 64 años. Sin embargo, no hubo diferencias significativas con los grupos de 20

a 34 años. Los resultados sugieren que las personas de 20 a 34 años y de 65 o más son más propensas a estar más activos en la lucha contra el CC.

En el segundo estudio sobre este tema pudimos emparejar las respuestas de los participantes entre el pretest y el post-test. Por lo tanto, utilizamos la prueba de Wilcoxon para muestras emparejadas. Aunque el proceso de análisis es muy similar al realizado en la parte A, mostramos algunas de las diferencias a continuación:

En primer lugar, la muestra utilizada en este apartado fue exclusivamente de profesores. Los resultados son muy similares a los obtenidos en el primer estudio sobre el MOOC MiriadaX: mejoran todas las subdimensiones de conocimientos y actitudes. Sin embargo, aunque todos presentaron mejoras en las actitudes, el apoyo educativo fue el único que presentó mejoras significativas tras realizar el curso. Por lo tanto, los profesores son más propensos a mejorar su comprensión del CC y a ser más activos en la lucha contra el CC, mejorando sus acciones de mitigación. Además, piensan que la educación es necesaria para hacer frente a este fenómeno y que estrategias como la creación de competencias como la C3 podrían desempeñar un papel positivo.

En segundo lugar, tras comprobar que nuestro MOOC mejora la C3 en toda la muestra, estudiamos el efecto de la variable género. Los resultados sugieren que las mujeres y los hombres mejoran significativamente sus conocimientos de CC. Sin embargo, las puntuaciones de las dimensiones de habilidades y actitudes fueron mayores en las mujeres que en los hombres. Por lo tanto, ambos tienden a aumentar la comprensión de la ciencia del CC mientras que las mujeres son más propensas a realizar acciones relacionadas con la mitigación y las actitudes contra el CC que los hombres. Sin embargo, es fundamental señalar que los varones presentaron mejores puntuaciones en conocimientos que las mujeres antes de comenzar el curso.

En resumen, los MOOCs pueden mejorar la comprensión de la ciencia del CC. Además, estos cursos tienen más posibilidades de mejorar para cambiar nuestras acciones a favor de la lucha contra el CC y las actitudes hacia este fenómeno. Además, los resultados de los elementos de mejora del C3 funcionan de forma diferente, dependiendo de las características sociodemográficas de la muestra. Por ejemplo, los profesores son más propensos a mejorar en C3 que los no profesores. Además, nuestros resultados explican que, aunque los españoles y los latinoamericanos mejoran en C3, estos últimos tienen más probabilidades de tener mejores habilidades y actitudes antes de comenzar una intervención como la de los MOOC. Cuando comparamos las acciones personales para luchar contra el CC con la edad, las personas de 20 a 24 años y las de 65 años o más son más activas en la lucha contra el CC. En cuanto al género, las mujeres son más propensas

a aumentar las acciones contra el CC para mejorar las actitudes que los hombres, sin embargo, ambos aumentan la comprensión de la ciencia del CC.

Los resultados reales de este capítulo demuestran que las estrategias de enseñanza como los MOOCs podrían ser una excelente alternativa para mejorar los conocimientos, las habilidades y las actitudes, lo que podría aumentar el compromiso para abordar el CC. Además, estos cursos ayudan a los profesores a percibir el CC como una cuestión socio-científica, en la que todos los elementos del C3 son necesarios para actuar eficazmente contra este fenómeno. Es fundamental destacar que la inclusión de la C3 en la educación formal podría ser una excelente estrategia para combatir el CC. Además, los MOOCs podrían aumentar la C3 de las ISTs porque son una herramienta en la que aprenden desde sus casas y toman las lecciones en su tiempo libre. Las actividades de formación como los MOOCs podrían implementarse en los PSTs para reforzar su comprensión de la ciencia del CC y otros elementos de la C3.

Chapter I

Background and objectives

1.1 Motivation

1.2 Objectives of the research

1.3 Main Findings

1. Chapter I. Background and objectives

1.1. Motivation

Climate Change (CC) is the greatest threat to civilization and all species living on Earth (IPCC, 2014b). Scientists worldwide have observed that never in the history of the Earth has there been such a rapid climate change as the one we have experienced since the Industrial Revolution, where human influence on natural systems has been observed (IPCC, 2013).

Faced with this, it is necessary to mobilize society within a timetable outlined by the United Nations Framework Convention on Climate Change through the Paris Agreement, which defines the total decarbonization of the economy by 2050. This agreement will be achieved through significant actions by governments, industries, and the support of people committed to the planet (United Nations, 2016).

The role of education in addressing the challenges of climate change is being increasingly accepted (Arto-Blanco et al., 2017; Buckler & Creech, 2014; Le Blanc, 2015; Mochizuki & Bryan, 2015; Quarderer et al., 2021). The Intergovernmental Panel on Climate Change (IPCC), created by the UN formed by 195 nations, is an organization that reports on the science of CC and informs policy for mitigation and adaptation. The IPCC has recognized for the first time explicitly the relevance of incorporating education into the strategic tools to address CC in the perspectives of adaptation and mitigation (IPCC, 2019).

In parallel, various global agreements and treaties recognize that educational support is essential in addressing CC. The Paris Agreement of the UNFCC recognizes that education is fundamental to mobilize society against climate change. It states that creating and implementing new strategies in education and awareness are necessary to keep the population informed. Through the Education for Sustainable Development (ESD), UNESCO aims to provide children and young people with the knowledge, skills, and attitudes necessary to make informed decisions and take responsible actions for environmental integrity, economic viability, and a just society. To this end, it encourages the creation of strategies that provide educators with the skills to empower and mobilize young people. The Sustainable Development Goals (SDGs) state that education is fundamental to face global challenges such as CC. It is, therefore, necessary to strengthen it to generate action against this phenomenon. A considerable number of international, national, and local programs exist to address education and CC, but the efforts are still small compared to the

scale of the CC challenge. Therefore, the creation of an effective strategic resource for mitigating and adapting to climate change continues to be necessary (Ruiz & Ferrari, 2019).

Many examples describe the need to create and implement an effective strategy to bring the CC into Education.

Education stakeholders in many countries have yet to develop a coherent framework for climate change education (Mochizuki & Bryan, 2015). Moreover, although there have been efforts, such as the inclusion in the curriculum of climate change content in elementary and secondary education, the amount of time dedicated to teaching CC continues to be minimal (Plutzer et al., 2016). Unfortunately, CC continues to be ignored by social and science signatures because most of these education programs do not relate to climate change with these disciplines (Reid, 2019). Even if CC science content is taught, it is not related to other disciplines such as economics, politics, or other human and social sciences (Herman et al., 2017), forgetting to treat CC as a socio-scientific problem (Boon, 2016).

Another possible explanation that could explain the absence of the CC in the curriculum is the issue's complexity. For instance, many teachers say they find it challenging to teach CC because they were not taught it during their teacher training process (Quarderer et al., 2021; Boon, 2016). In addition, a study found that for most teacher training programs, teaching content on environment and CC is not obligatory (Hestness et al., 2011). Some pre-service science teachers (PSTs) even stated that they do not find CC content in their curricula (Seroussi et al., 2019). Other research showed that only 4% of the different universities in Spain have CC in their curricula (Sureda-Negre et al., 2014).

Although CC forms part of the curriculum of elementary and secondary schools, the teachers sometimes do not teach it, or they don't do it properly because it is a subject that they do not dominate sufficiently. Several studies explain that the science behind this phenomenon is difficult to understand (Oversby, 2015), and there are many misconceptions on PSTs (Liu et al., 2015) or in-service teachers (ISTs) (Dawson, 2012). For instance, some studies point to conceptual misconceptions or deficiencies in the science of CC. According to Herman et al. (2017), ISTs, and Nyarko & Petcovic (2021), PSTs believe that the hole in the ozone layer is a cause of CC and that produces major radiation in the atmosphere. This belief was also observed in high school (Bello Benavides et al., 2017) and university students (Gutiérrez-Pérez, 2015; Meira-Cartea et al., 2018). Another example of lack of knowledge about science CC on teachers is the difficulty distinguishing

between such simple concepts as global warming and the greenhouse effect (Arslan et al., 2012). According to Wise (2010), the ISTs cannot differentiate between climate and weather. The lack of knowledge about the causes of CC is also another critical issue. Hestness et al. (2014) indicate that ISTs believe that humans are not to blame for CC. For example, one in five U.S. ISTs believes that CC is attributed to natural causes (Plutzer & Hannah, 2018). Moreover, other PSTs even deny the existence of CC (Higde et al., 2017).

Furthermore, the misconceptions are presented in issues related to behaviors and abilities to mitigation. For instance, according to Ikonomidis et al. (2012), most PSTs believe that any eco-friendly action can mitigate CC. Activities such as recycling and cleaning beaches are identified as potential actions to address CC and consume less, using nuclear energy and saving energy are considered weak actions. Most of the ISTs are unaware of the actions to remedy the consequences of CC (McNeal et al., 2014).

Attitudes are another essential element that may explain the deficits of CC in education. Sadly, many ISTs show a low level of willingness to adopt actions that address the CC (Ambusaidi et al., 2012). According to Karami et al. (2017), most ISTs in Iran present a low level of Attitude in CC, even lower knowledge. Another element associated with attitudes is distrust in the media about CC. According to Boon (2016), one of the main barriers influences PSTs' low knowledge of the causes, consequences, and actions to address CC. According to Ferrari-Lagos et al. (2021), most teachers are unaware of sources such as IPCC or NOAA.

Other studies argue that the teaching of CC presents problems because its content is interdisciplinary (Hugé et al., 2017). Other researchers say that many teachers consider the content on CC to be controversial (Seow & Ho, 2016). As seen before, this brings a big problem because, once teachers are placed in the education system, they lack knowledge about the science of this phenomenon, the causes, consequences, actions for its mitigation, and strategies for its teaching and awareness (Seroussi et al., 2019). Teachers have the challenge to study this phenomenon on their own and often find themselves with statements based on uncertain and partial data that challenge the actual reality of the problem (Ruiz & Ferrari, 2019).

The current thesis project was born from the need to create solutions for the problems described above through a strategy that allows to work in knowledge, abilities, and attitudes around the science of CC in PSTs and ISTs, as well as the proper implementation of contents and didactics of CC in teacher training institutions and the educational system in general. Our main proposal is

the introduction of a competence that we will call Climate Change Competence (C3). This will serve as a tool to implement several aspects related to CC proposed in international treaties and frameworks such as the Paris Agreement, ESD, and SDGs.

These frameworks address important issues such as sustainability and many other important global challenges. However, CC differentiates it from these issues because of its urgency (Gutiérrez-Pérez et al., 2020). Therefore, we decided to propose C3 as a strategy based on education concepts. This competence will allow the introduction of the state of the art contributions in the literature on climate change education (CCE) as well as the latest and best available science on climate change including the important institutional frameworks mentioned above.

There are three main dimensions in this competence. The first, called *learning to learn*, explains the science behind this phenomenon, the complexity of the CC problem, and the impact of human activity as the leading cause of this phenomenon and future scenarios if we do not decarbonize the economy by the year 2050. The second element is *learning to do*, where personal and collective actions are developed to face this phenomenon, looking for solutions at an individual and collective level. Finally, the last element is *learning to be*, this dimension develops knowledge into action through attitudes and actions. This includes important value as the recognition that this is a global problem which requires individual, local, national and international efforts and the acknowledgement that our efforts are significant together with the acceptance of public policies and critical thinking around this phenomenon and its consequences.

The concept of C3 is helpful to collect and organize all the knowledge and contributions around ECC. However, it also is helpful to design new materials, strategies, and educational interventions to improve the C3. Among the many strategies and educational activities that can be made around the C3, in this thesis, we investigate the effect of training activities such as Massive Open Online Courses (MOOC).

Several elements make MOOCs an essential and effective tool to advance the C3. It has been demonstrated that these learning tools can increase climate literacy in citizens (Burch & Harris, 2014; Ferrari et al., 2019; Otto et al., 2019). Therefore, we propose it as an alternative to improve the elements of C3 in the citizens. For this purpose, we have created and designed a MOOC to develop it in the teachers, offering them the best available science provided by scientists through the IPCC reports, pedagogy, and different teaching methodologies. In the development of this thesis, three different versions of MOOCs have been created so far. These have been distributed

on three different platforms: MiriadaX, Center for Teacher Training and Educational Innovation of Castilla y Leon (CFIE), and the National Institute of Educational Technologies and Teacher Training (INTEF). The three modalities are characterized by a simple structure designed to answer: What is CC? What causes CC? What are the consequences if we do not act? And what can we do from education? These questions are answered in six modules. In the current monograph, we present the results of two of the three versions developed. In them, we will evaluate teachers' performance and identify the groups with the best performance, as well as the improvement of C3 at the end of the MOOC.

On the other hand, this project contributes to expanding the need to create training programs such as this one, which, being offered openly, tries to reach the maximum number of teachers. With this, we expect to contribute to the training of children and young people to become leaders of sustainability through education, mobilization, and awareness to face the challenges of climate change.

1.2. Objectives

This thesis includes six chapters, each with different levels of scope (explanatory, descriptive, correlational, inferential). Using all these levels allowed us to obtain a complete picture of the Climate Change Competence (C3).

1.2.1. Chapter II. "Definition and justification of Climate Change Competence"

Education has been considered as a fundamental source to mitigate CC. However, there is not yet a complete and coherent strategy to introduce CC into education. Therefore, in this chapter, we introduce climate change competence (C3), its context and its justification.

The general objective of this study was:

- Establish an educational competence as a strategy to introduce CC to education.

To be achieved through the specific objectives:

- To identify the elements of C3 in elementary and secondary Pre-Service Teachers (PSTs) and In-Service Teachers (ISTs)
- To describe the elements of C3 in elementary and secondary (PSTs) and (ISTs).
- To describe the MOOCs as tools of learning to develop the C3 in elementary and secondary (PSTs) and (ISTs).

1.2.2. Chapter III. "Theoretical framework and scale validation of the Climate Change Competence in Education"

Theoretical factors obtained in the preparation stage developed in Chapter II were used. This stage allowed the construction of models that represent the structure of C3. In addition, each element (knowledge, ability, and attitude) of the climate competence was validated on independent scales.

The general objective of this study was:

- To design an instrument to assess C3 in elementary and secondary (PSTs) and (ISTs).

To be achieved through the specific objectives:

- To determine the model more appropriate to assess the elements of C3 in elementary and secondary (PSTs) and (ISTs).

- To develop a scale that independently assesses the aspects of C3 of elementary and secondary (PSTs) and (ISTs).

1.2.3. Chapter IV "Examining the relationship between the dimensions of the Climate Change Competence (C3): Testing for mediation and moderation."

The results of scales of C3 elaborated and applied in previous chapters were used to determine the type of relationship between elements of the competence. This allowed us to know and identify the factors that could predict others. In addition, the moderation of these elements could increase the values of the features of competence.

The general objective of this study was:

- To evaluate the relationships between the dimensions of C3 in elementary and secondary (PSTs) and (ISTs).

To be achieved through the specific objectives:

- To describe the relationships among the dimensions of C3 in elementary and secondary (PSTs) and (ISTs).
- To estimate the levels of abilities and attitudes through scientific knowledge of C3 of elementary and secondary (PSTs) and (ISTs).
- To demonstrate that attitudes moderate the relationship between knowledge and abilities.

1.2.4. Chapter V "Assessment of climate competence in elementary, secondary and pre-service school teachers."

The scales of C3 elaborated in chapter III were applied in elementary and secondary (PSTs) and (ISTs). This allowed us to know and identify the levels of elements of knowledge, abilities, and attitudes. In addition, identifying groups of teachers with higher levels is essential since these could motivate others with low levels of competence.

The general objective of this study was:

- To determine the levels of knowledge, abilities, and attitudes in elementary and secondary (PSTs) and (ISTs).

To be achieved through the specific objectives:

- To compare the levels of knowledge, abilities, and attitudes of elementary and secondary (PSTs) and (ISTs).
- To differentiate the levels of knowledge, abilities, and attitudes in PSTs and ISTs by level (primary and secondary) and area (experimental science and social science) of teaching.

1.2.5. Chapter VI.A "Can learning science be the key to promote positive attitudes and abilities towards Climate Change? Improvement of the Climate Change competence through a knowledge-based MOOC."

In the present chapter, we assess the effectiveness of a MOOC based on knowledge on the science of CC. This could produce a chain reaction. In other words, if we increase the knowledge on CC, we hope to improve the levels of abilities and attitudes of C3 as well.

The general objective of this study was:

- To assess the importance of MOOCs as an alternative for improving C3 in participants of the course.

To be achieved through the specific objectives:

- To describe the importance of MOOCs as a tool for improving the C3 of participants of course.
- To demonstrate that MOOCs improve the dimensions of C3 in participants of the course.
- To compare the improvement of C3 through MOOCs in teachers and non-teachers.
- To compare the improvement of C3 through MOOCs in people from Spain and Latin America.
- To compare the levels of abilities of C3 by age.

1.2.6. Chapter VI.B "Effect learning science on empowering abilities and attitude to act on Climate Change. Enhance of the C3 through a knowledge based MOOC."

The current chapter aims to show that the C3 of teachers is enhanced through a MOOC on CC.

The general objective of this study was:

- To increase the C3 of elementary and secondary (ISTs) towards a MOOC.

To be achieved through the specific objectives:

- To demonstrate that a MOOC improves the dimensions of C3 in elementary and secondary (ISTs)
- To compare the levels of knowledge, abilities and attitudes of C3 by gender.

1.3. Main Findings

Once we have introduced the motivation and the objectives to achieve in the current project, we describe the main result of the thesis, and we outline how all these results are organized. The results are grouped into four main parts. First, we propose climate change competence (C3) as a strategy to introduce CC in education. Second, we explain the creation and validation of an instrument called C3-Q, which will assess C3 in PSTs, ISTs, and the general public. In addition, we explain how the elements of C3 (knowledge, abilities, and attitudes) are connected. Third, assess C3 in groups and show its characteristics that have been developed for this thesis. Finally, in part fourth, we present results on the effect of an educational intervention on the C3. These results are organized through the papers that are presented in chapters III to VI. The current section presents a summary and highlights the main results of these chapters.

Chapter III is dedicated to validating an instrument to assess the C3 in the general public, teachers, and students.

Once that, we have provided context, motivation, and the need to create competence. We started the process of the formal definition of the C3. A content analysis was performed using the reports from the IPCC (2014), SDG (2015), and the Paris Agreement (2016) and an exhaustive literature review, which served to identify the elements that this competence should include. In

addition, we included the opinions of different specialists in CC science and CCS, PSTs, and ISTs that were collected during a series of seminars developed at the University of Salamanca. This allowed us to develop an instrument reviewed by eight faculty members of Education of the University of Salamanca. They are part of the research team Mathematics, Education, Science and Climate Change (EMC3). After this, a pilot study was conducted, selecting the items that would be part of the C3 and elaborate our theoretical model. After the content analysis, the collection of opinions of the leading agents, expert judgment, and the pilot study, the instrument was finally applied for validation. The results of this process are shown in Chapter III. The questionnaire was applied to 530 participants of the second edition of the MOOC "Climate change awareness and training for elementary and secondary school teachers." Since the construct is new and its structure was unknown, an exploratory factor analysis (EFA) was applied. This revealed an initial structure of three independent scales, known as dimensions, consisting of knowledge (biophysical processes, causes, consequences, adaptation, and mitigation), abilities (purchases, transport, and energy-saving), and finally, attitudes (responsibility to act, trust in the source information and support of education). Once it was demonstrated that C3 could be measured as a construct, it was tested by confirmatory factor analysis (CFA). Four models (one-dimensional, multidimensional, second-order, and bifactor) were evaluated in the CFA. The bifactor model showed the best indices in all three scales. Therefore, the instrument to determine the C3 will be called C3-Q.

These essential results allowed us to understand that C3 is a construct that could be analyzed through its dimensions and, more specifically, through its sub-dimensions. Moreover, the C3-Q could be considered a valuable tool to evaluate it in individuals and groups.

The first findings of C3 are presented in **chapter IV**. We have analyzed the C3 to determine the type of relationship between elements of the competence. For this proposal, we divided the study into three parts.

First, to determine how the knowledge, abilities, and attitudes of C3 affect each other, we applied a correlation analysis. The result obtained was that CC knowledge has a moderate positive correlation with CC abilities and attitudes.

Second, understanding that the dimensions of C3 present positive correlations between them, we examined the impact of knowledge on abilities and whether attitudes mediate them. To this end, a series of regression analyses were carried out. The result showed that knowledge positively predicted abilities. In addition, the results revealed that attitudes significantly mediate the relationship between knowledge and abilities.

Third, we examined the relationship between knowledge and attitudes while determining whether abilities were a moderating variable in this relationship. For this purpose, a multiple regression analysis was carried out. The simple slope analyses reveal a positively predicted attitude at low, average, or high ability levels. Thus, the analysis suggests that individuals who perform many activities related to CC mitigation (have high levels in the ability dimension) are more likely to create awareness to act against CC, even when the level of scientific knowledge about CC is low.

In sum, the results indicate that knowledge in CC is more likely to provide ability and attitudes in CC. In addition, the findings provide some evidence that people who have scientific knowledge about the science of CC are more likely to make activities related to CC mitigation; because they tend to create an awareness to act against CC with growing autonomy, judgment, and personal responsibility. Finally, the results explain that the ability in CC strengthens the relationship between this knowledge and attitudes of the C3.

These are important findings that demonstrate empirically that the dimensions of competence are not independent. The definition of the C3 and the assessment tools allow us to show these correlations, which may be helpful to design further educational interventions or identify the source of deficits on the C3 and act accordingly. This also means that advancing some dimensions may positively affect the other and set some priorities to design curricula or new materials.

In **chapter V**, we have assessed C3 in elementary and secondary Pre-Service Teachers (PSTs) at the USAL and elementary and secondary In-Service Teachers (ISTs) from Castilla y Leon. In this case, the C3-Q (our instrument to assess C3) elaborated in chapter III were applied both. The principal objective in this chapter is to observe if there will be differences in the elements of C3 in PSTs and ISTs by level (primary and secondary) and area (experimental science and social science) of teaching. To achieve this purpose, the analysis of this chapter was divided as follows:

First, we compare the levels of knowledge, abilities, and attitudes of C3 in PSTs and ISTs by the level of teaching. We use a nonparametric Mann–Whitney U test. The results revealed that the knowledge of the secondary PSTs and ISTs regarding biophysical processes (BPP) and consequences (CSQ) was significantly higher than elementary PSTs and ISTs. Moreover, the A&M sub-dimension was significantly higher in secondary PSTs. Hence, previous results indicate that secondary school PSTs and ISTs are more likely to understand the science of CC, specifically the PBB and CSQ. In terms of the ability dimension, the transport was only one sub-dimension significantly higher in the secondary PSTs and ISTs. The purchases sub-dimension presented a

significant score higher in secondary PSTs. Therefore, secondary school PSTs and ISTs are more likely to take personal actions in their daily lives related to the use of transportation, such as carpooling, using public transport, and walking. In addition, secondary PSTs are more likely to consume local and sustainable products. In attitude, there were no significant differences.

Second, to compare the elements of C3 in PSTs and ISTs according to their area of expertise, we also use a nonparametric Mann–Whitney U test. In terms of knowledge, PSTs and IST with training on experimental science had higher scores than social science PSTs and IST, respectively, in BPP and CSQ sub-dimensions. Thus, our results suggest that experimental science PSTs and ISTs have a better dominance of knowledge of the science of CC. In the ability dimension, the transport sub-dimension was the one that presented significant differences; PSTs and ISTs with training in social sciences showed higher scores than those PSTs and ISTs with training in experimental science. Therefore, PSTs and ISTs trained in social science are more likely to walk, carpool, or take the bus to move around. In terms of attitudes, trust in sources of information and education support were sub-dimensions where PSTs and ISTs trained in social science school scored higher than PSTs and ISTs trained in experimental science school; however, the differences were not significant.

Third, we compared if there was a significant difference in the trust in the agents of the information about CC. We applied a Friedmann ANOVA to each source of information (Scientists, Teachers, Environmental groups, Media, and UN). The findings suggest that PSTs and ISTs are likely to be least trusted to receive information on CC from the Media. In contrast, the scientists are the group with the highest average rankings compared to the others.

Overall, this chapter suggests that primary PSTs and ISTs have little knowledge of CC science, leading to less engagement with CC activities. Therefore, there is a need to bring science closer to primary school PSTs through hands-on activities. The elementary ISTs could learn more about the science of this phenomenon using online courses such as MOOCs to advance at their own pace. Furthermore, this chapter also recognizes that knowledge of the science of CC alone is ineffective if it is not related to the social part. Therefore, to mobilize society to action, we need to study this phenomenon with all the elements of C3 (knowledge, abilities, and attitudes) from the social and scientific perspective. PSTs and ISTs with training in experimental science must understand that CC is also a human problem and that it is impossible to address it with science and technology alone. In addition, it is essential to teach the science of CC from scientific sources, as this is the most credible group to report on issues related to this phenomenon.

The critical results in this chapter demonstrate that we can measure the level of competence between different groups and identify the origin of those differences. This significant finding

proves the power of the C3 and the assessment tools to create sophisticated diagnostics on the current level of the C3 and the factors that can explain the significant differences between each group.

Finally, in **Chapter VI**, we show whether it is possible to increase C3 through MOOCs. For this purpose, we divide this chapter into two studies based on the courses offered to teachers. The first study shows the results of the second edition of the course "Climate change awareness and training for elementary and secondary school teachers" developed on the MiriadaX platform. The second study presents the results of the first and second editions of the course "Science of Climate Change" offered on the Center for Teacher Training and Educational Innovation (CFIE) platform of Castilla y León. The C3-Q elaborated in chapter III was applied using a pre-experimental design, with pre-and post-test measurements. We used the nonparametric Mann–Whitney U test because there was experimental death and the responses to the questionnaires were anonymous. We were unable to match responses from the pre and post-test. The independent variable was the MOOC, and the dependent variables were every one of the sub-dimensions of the C3. Both sections aimed to assess if there was an increase in the levels of C3 of the participants towards MOOC. In the first study, the analysis was divided as follow:

The first part is dedicated to assessing whether our MOOC improves the dimensions of C3. In the knowledge dimension, all the sub-dimensions presented an improvement after the course. This explains that the participants improved their understanding of the basic concepts of BPP, CAU, CSQ, and A&M on CC. Likewise, the ability dimension presented improvement in all its sub-dimensions. The results reveal that students increased their actions against CC after taking the course. In terms of attitudes, the sub-dimensions that showed improvement were trust and educational support. However, responsibility did not show significant improvements.

In the second part, we compare the improvement of C3 throughout the course in teachers and non-teachers. In terms of knowledge, both groups showed improvement; This explains that the course increased the understanding of CC. However, for the abilities and attitude dimensions, only the teachers showed significant improvement. The results reveal that teachers are more likely to improve their actions to fight CC and their attitudes after the course.

In the third part, we compare the improvement of C3 throughout the course in Spanish and Latin-American people. The results suggest that both groups increase the C3 in all dimensions. However, the levels of ability and attitudes were higher for Latin-American participants before starting the course. Thus, the results indicate that Latin Americans are more likely to act against CC and have better attitudes towards this phenomenon.

In the fourth part, we compare the ability dimension by age group. We use a nonparametric Kruskal Wallis test. The results revealed that the ability dimension tends to decrease with age. However, this trend changed for the group of 65 or older. Scores in ability were higher in 65 or older group than 35 - 49 and 50 - 64. However, there were no significant differences with groups of 20 - 34. The results suggest that people between 20 to 34 years of age and 65 or older are more likely to be against CC.

In the second study on this topic, we were able to pair the participants' responses between pretest and post-test. Therefore, we used the Wilcoxon test for paired samples. Although the process of analysis is very similar to the one performed in part A, we show some differences as follow:

First, in addition, the sample used in this section was exclusive of only teachers. The results are very similar to those obtained in the first study about the MiriadaX MOOC; they improve all sub-dimensions of knowledge and attitudes. However, although all presented improvements in attitudes, educational support was the only one to present significant improvements after taking the course. Therefore, teachers are more likely to improve their understanding of CC and be more active in the fight against CC by improving their mitigation actions. In addition, they think that education is necessary to cope with this phenomenon and that strategies such as creating competences like C3 could play a positive role.

Second, after verifying that our MOOC improves the C3 in the whole sample, we study the effect of variable gender. The results suggest that females and males improve significantly in their knowledge of CC. However, the scores of dimensions of abilities and attitudes were higher in females than males. Hence, both are more likely to increase the understanding of the science of CC. In contrast, females are more likely to take actions related to mitigation and attitudes against CC than males. However, it is essential to note that the males presented better scores in knowledge than females before starting the course.

In sum, MOOCs can improve understanding of the science of CC. Likewise, these courses are more likely to improve to change our actions in favor of fighting CC and attitudes towards this phenomenon. Moreover, the results of the elements of C3 improvements work differently, depending on the sociodemographic characteristics of the sample. For example, teachers are more likely to improve in C3 than no-teachers. Also, our results explain that although Spaniards and Latin Americans improve in C3, the latter are more likely to have better skills and attitudes before starting an intervention such as MOOCs. When we compare personal actions to fight CC with age, people aged 20-24 and those 65 and older are more active in fighting CC. In terms of gender,

females are more likely to increase actions against CC to improve attitudes than males. However, both increase the understanding of the science of CC.

The actual results in this chapter demonstrate that teaching strategies such as MOOCs could be an excellent alternative to improve knowledge, abilities, and attitudes, which could increase engagement to address CC. Furthermore, these courses help teachers to perceive CC as a socio-scientific issue, in which all the elements of C3 are necessary to act effectively against this phenomenon. It is essential to emphasize that the inclusion of C3 in formal education could be an excellent strategy to combat CC. Moreover, MOOCs could increase the C3 of ISTs because they are a tool where they learn from their houses and take the lessons in their free time. Training activities such as MOOCs could be implemented in the PSTs to reinforce their understanding of the science of CC and other elements of C3.

Chapter II

Conceptual framework

2.1 Evidence of Climate Change

2.2 Importance of Climate Change Education

2.3 Climate change competence

2.4 Tools and Learning programs

2.5 Assessment of climate change competence

2.6 Summary of results

2. Chapter II. Conceptual framework

In this chapter, we present the context of Climate Change and Education by describing different initiatives around the issue, its relationship with the ESD and the SDG, and other initiatives. We will then describe the different approaches to include the CC into Education. We will introduce the C3, its context, and how the dimensions and sub-dimensions are defined. Also, we will describe why its assessment is essential and how to do that assessment.

2.1. Evidence of Climate Change

The UN's Intergovernmental Panel on Climate Change (IPCC) is the group of scientists that monitors and assesses human influence on the planet's natural systems. They explain that the most substantial evidence of climate change is the increase in global average temperature between 0.5 °C to 1.3 °C between 1951 and 2010. Periodically, they make reports about the changes that have affected the weather system of the planet. AR5 (2014) was a report in which IPCC scientists describe the planet's changes in recent decades. In the previous report, the scientists showed evidence that CC is changing the climate balance on the planet. For instance, the ocean's salinity has changed, the amount of oxygen has decreased, as well as the mantle and permafrost in high latitude regions are melting, causing sea levels to rise (IPCC, 2014b). The evidence is clear.

In response to address CC, the nations of the world have developed actions to adapt and, above all, to mitigate this phenomenon. One way to address it is through education (Lutz et al., 2014). Therefore, the following section explains the importance of education in responding to this phenomenon.

2.2. Importance of Climate Change Education

Increasingly, the field of education is recognized by international organizations to tackle CC. For instance, in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was created by the UN. One hundred and fifty-four countries signed this environmental treaty to stabilize greenhouse gas concentrations in the atmosphere at a level that the human does not alter the equilibrium of the weather system. Article No. 6 of this framework is dedicated to training, awareness, and access to information on climate change (United Nations, 1992). This was the beginning, in which the ecologic, social, and economic system received support because of work together between thinking and action. This initiative was the first to appreciate the importance of education in tackling such sustainable development.

A few years later, the Decade of Education for Sustainable Development (DESD) 2005-2014 began. During this decade, the UN, through UNESCO, designed programs around the World whose sole objective was to use the benefits of education in creating a more sustainable world, addressing economic, social and environmental aspects (Buckler & Creech, 2014). As a result, many countries modified and adapted their curricular education programs to include different topics to achieve this objective in all education levels. For instance, in Early Childhood Care, several play-based learning was focused on enhancing nature awareness. In Elementary and Secondary Education, many teachers received training about adapting pedagogically to the Education for Sustainable Development (EDS) in their lesson classes. In addition, the Technical and Vocational Education adopted tools to encourage the EDS and make sure that the community and workplace of the students were also influenced (Buckler & Creech, 2014).

Following these frameworks, in 2015, the UN adopted the 2030 Agenda on Sustainable Development. This agenda was formed by 17 goals (figure 2.1), called Sustainable Development Goals (SDGs), where themes such as the topic climate change and sustainability are central.

Figure 2.1. *Sustainable Development Goals. Reference: UNESCO (2015)*

However, Rieckmann (2017) at the request of UNESCO, elaborated a book which related education with the 17 SDGs and although most of these objectives integrate education with sustainability and climate change, we have selected 3 of them. First, SDG-4 “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”. Second, SDG-12 “Ensure sustainable consumption and production patterns". Finally, SDG-13 “Take urgent action

to combat climate change and its impacts". Each of the 17 goals includes fifteen specific goals to achieve with education and are classified as cognitive learning, socio-emotional learning, and behavioral learning. For SDG-4, in one of its sections, more specifically 4.7, argue that all the knowledge and skills are necessary to support sustainable development. For instance, a sustainable lifestyle all students have to be enhanced through education. SGD-4 emphasizes that education is an important way to create a more sustainable world. In addition, it provides the knowledge necessary to encourage sustainable development in the everyday life situations of citizens. SDG-12, cognitive learning objectives are associated with the importance of personal lifestyle and practice on the reduction of emissions of CO_2. Socio-emotional learning objectives could be achieved if we communicate to others strategies in consumption. Some of the targets of this objective are shown in Figure 2.2.

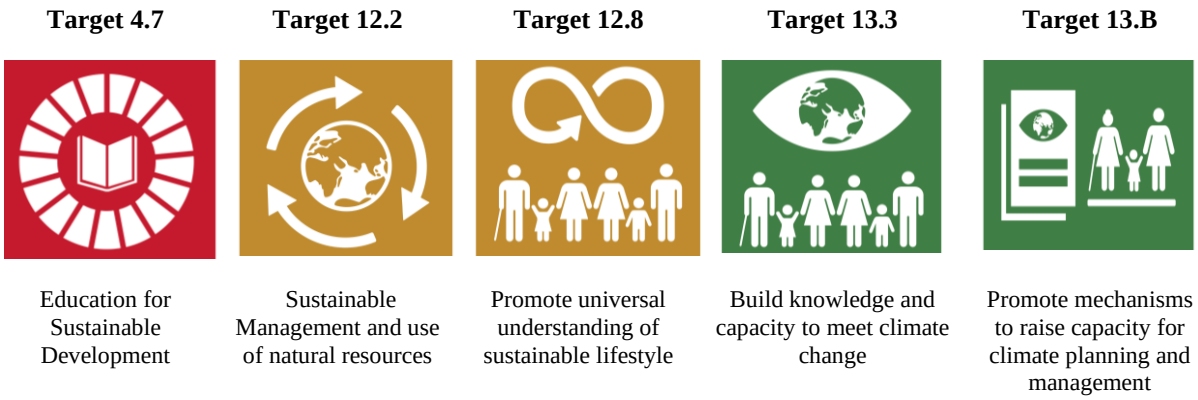

Figure 2.2. *Targets of ODS related with CC. Reference: UNESCO (2015)*

Finally, behavioral learning objectives are related to how responsible behavior is essential to influence others. SDG-13 explains why education is crucial to achieving it. This goal, described as Climate Change Education (CCE), should be implemented on all education levels (Early Childhood Care, Primary and Secondary), as was adopted by DESD. For instance, in Early Childhood Care and Education, UNESCO suggests that the classes about nature or forest support the skills in gardening and increase the curiosity and the investigation in these themes. For Primary Education, the science about climate is essential, as such the consequences of this phenomenon on the planet.

The concepts related to mitigation (Human action aimed at reducing the sources or enhancing the sinks of GHG) and adaptation (Process of adjustment to the actual or projected climate and its effects) are fundamentals (IPCC, 2014b), such as recycling and consuming responsibly in electricity and others associated with reducing greenhouse gas emissions. Education

is an essential tool to improve the understanding and application of these concepts (IPCC, 2019; Lutz et al., 2014; UNESCO, 2016).

The UNESCO portal provides several pedagogical and multimedia educational resources on its website, and that could apply such activities in all levels of education. For SDG-13, cognitive learning objectives are relationships with understanding climate change as a phenomenon by humans, and that is our activities influential to mitigating it. Socio-emotional learning objectives explain that to achieve the SDG-13, it is necessary to understand that can be mitigated with personal and social strategies. It is a phenomenon that affects not only the environment but society and the economy as well. Finally, behavioral learning objectives explain the importance of adopting climate-friendly strategies and assessing our activities' impact (United Nations, 2015).

Another framework, the Paris agreement, was created in 2015 to keep below 2 degrees Celsius above pre-industrial levels and make efforts to limit them to 1.5 degrees through a solid response to reduce greenhouse gases (United Nations, 2016). Once again, the field of education is recognized as a necessary resource for this objective. Thus, articles 11 and 12 include the importance of improving climate change education to prepare people to face this phenomenon through training, public participation, and access to information. (United Nations, 2016).

All these treaties recognize the importance of education. Therefore, they have included it as support in the improvement to create and enhance awareness of the influence of humans on climate change mitigation, adaptation, and impact reduction. Table 2.1 shows a summary of these conventions.

Table 2.1. *Conventions on CC that Include Education*

Treaty	Year	Objective	Support education
UNFCCC	1992	To stabilize greenhouse emission concentrations at a level that might avoid unsafe human-induced interference with the climate system.	To training, awareness, and access to information on climate change
DESD	2004	To allow a more just society through inclusion values sustainable development to education to improve the behavior.	To design programs for education to create a more sustainable world.
SDGs	2015	To end poverty, protect the earth, and guarantee that everyone can	Develop new competences through the

		enjoy peace and thrive by 2030.	introduction of pedagogies that empower citizens for a sustainable society
Paris agreement	2016	To keep below 2 degrees Celsius above pre-industrial levels and make efforts to limit them to 1.5 degrees through a solid response to reduce greenhouse gases.	Training and awareness-raising to understand the importance of strategies of the Paris agreement.

Education is essential to combat against CC (UNESCO, 2020). Therefore, it is introduced in the latest framework developed by UNESCO called "Education for Sustainable Development: Towards achieving the SDGs." This framework was called “EDS for 2030” as well, in it the ESD aims to provide students with the knowledge, abilities and attitudes to act against this phenomenon and at the same time support the achievement of the SDGs (UNESCO, 2019). Figure 2.3 shows the UNESCO embed of CC in education.

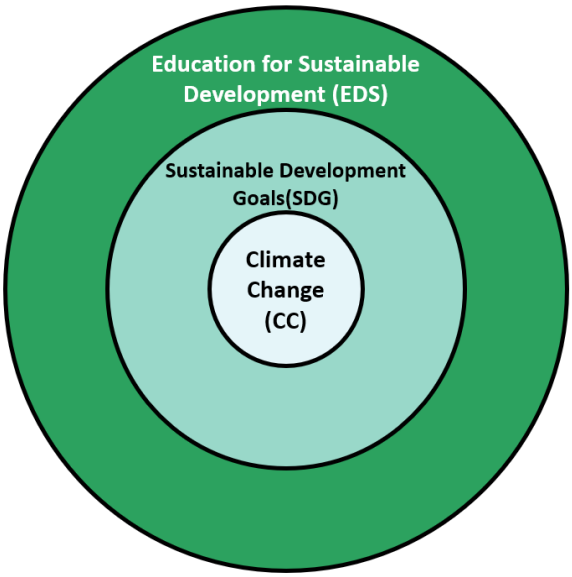

Figure 2.3. *Embed of CC in education by UNESCO*

2.3. Climate change competence

2.3.1. Basic concepts of competence

In the last decades, competence models have been used by several international organizations such as states, educational institutions, teachers, and academics in the field of pedagogy (Delors, 1997). For instance, in 2006, European countries created the key competences

to lifelong learning, as a need for its citizens to address the changes and challenges of the 21st century, such as personal realization, a healthy and sustainable lifestyle, climate change, employability, and active participation in citizenship, and social inclusion.

However, what does the competence approach have that the other models do not? Many education specialists explain that the competences have emerged as an alternative to address the weaknesses of traditional pedagogical models and approaches, such as behaviorism, cognitivism, and constructivism. For example, Tobon et al. (2010) explain that the competence model is more efficient because it offers some advantages that traditional models do not tackle with clarity, such as:

- Make the curriculum, the learning and assessment process relevant to the students, and the local, national, international, current, and future context dynamics.
- Train people to face daily problems by integrating and mobilizing learning to be, learning to do, and learning to know, considering the challenges of the context.
- Train people with critical, reflective, analytical, and creative skills to apply in everyday life.

Another advantage that offers the competence model is that it supports the approach and interaction of educational institutions with society and its dynamics of change to contribute to social and economic development and environmental and ecological balance. All these advantages consider the changes in the social, professional, scientific, and labor contexts, and so forth, which means that the competency model tends to consolidate more and more every day and become the new educational paradigm.

However, the competence model is not a very different paradigm from the traditional one because some of their theoretical and methodological approaches support it. For instance, many didactic and evaluation techniques have been taken from constructivism, with which it is more closely related.

Nevertheless, how do we define the competency-based model? There are multiple definitions from the professional field, but we will focus mainly on the educational area for this study.

Below is a summary of definitions of competences:

- The European Commission (2018) defines competences as a combination of knowledge (concepts about a certain area), skill (ability to use the knowledge to acquire desired results) and attitude (willingness to act towards situations, ideas and people).

- OECD (2018): competence is the capacity to move knowledge, abilities, attitudes and values, together with a reflection-based approach to learning processes, in order to engage with and act in the world.
- Tobon et al. (2010) define them as necessary actions in the face of activities and problems of the context, with suitability and ethical commitment, integrating learning how to be, learning how to do, and learning how to know in a perspective of continuous improvement.
- The Royal Spanish Academy defines them as incumbency, expertise, aptitude, and suitability to do something or intervene in a given matter (RAE, 2021).
- Zabala & Arnau (2008) argue that competences involve the mobilization of a set of resources possessed by the individual. Thus, the purpose of competences is the performance of practical or excellent tasks.

The components of competence can be divided into (Delors, 1997; Martínez Clares & Echeverría Samanes, 2009; Villa Sánchez & Poblete Ruiz, 2006):

- **Learning to know**: Set of knowledge (general and specific, as well as theoretical and practical).
- **Learning to do**: Skills and abilities resulting from learning and experience.
- **Learning to be**: Values and attitudes.

The components described by Delors (1997) explain that to be competent is necessary to possess more than only knowledge; it is essential to apply it in activities and problems with quality, integrating an ethical performance based on values and attitudes. Another example is described by OECD (2006), where scientific competences require an interest in and appreciation of science for its support to the development of society, and not only knowledge and skills in the methods to extract data and conclusions. In other words, to be competent, it is necessary to understand, contextualize and analyze practical actions based on concepts and theories, and carry them out with an ethical engagement. Therefore, as Tobon et al. (2010) explained, being competent is not learning to know, learning to do, and learning to be separate. Instead, it is necessary to mobilize the different

learning (being, doing, and knowing) towards achieving a specific goal in the context, as shown in Figure 2.4.

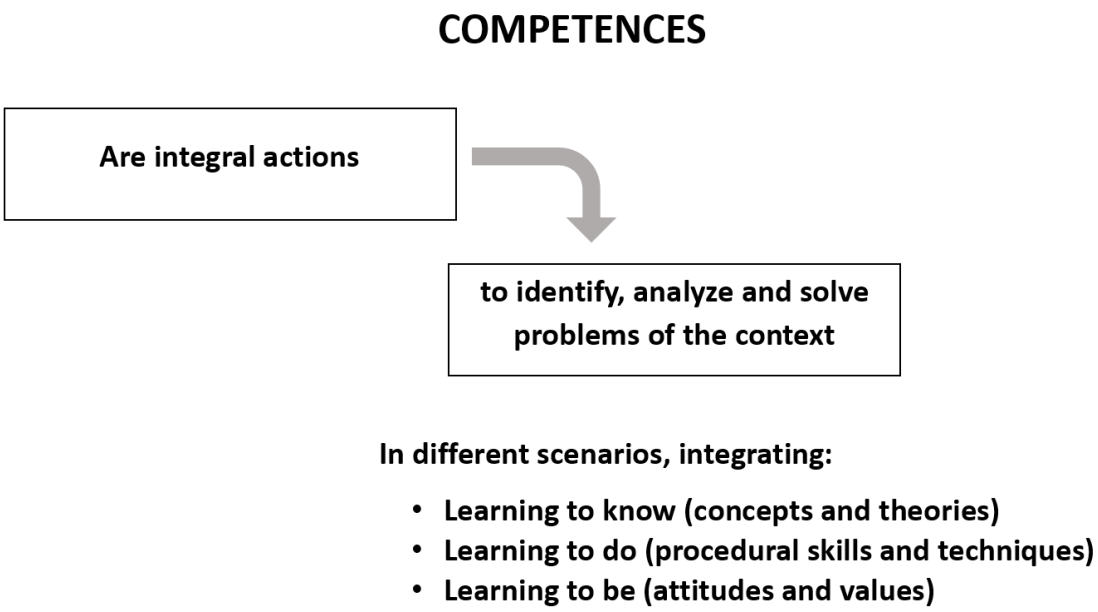

Figure 2.4. *Concept of competences. Reference: Tobón (2009).*

2.3.2. Competences relationship with climate change

As we can see, every day, the competences are proposed by different international organizations, where education is used to develop them. For instance, as mentioned previously, The European Council (2006) created eight key competences as Citizenship competence, Personal, social, and learning to learn competence, and Cultural awareness and expression competence. Furthermore, in 2018, The Commission European Staff elaborated a Proposal for a Council Recommendation as a necessity of answer to the current changes and challenges between these "climate change." This proposal suggests that CC have to be tackled on science, technological, engineering, and mathematical competence as well as Civic competence (European Commission, 2018b). Finally, the Council of the European Union decided to approve this recommendation where knowledge about CC is necessary to face this phenomenon (European Union 2018a), and the education system should support this. Furthermore, this new update on key competences would bring back SDG, especially SDG 4.7.

Sustainability, climate change, and others need to be addressed by a competence model. For instance, many pedagogues and other education specialists have designed and developed different competences such as:

- Environmental Competence (EC): it is described as the skill to cope effectively with the immediate environment (Steele, 1980). A study from Pedersen (1999) defined the following components: conscientious (especially about recycling such as: sorting garbage to be placed in containers, find another use for damaged things, avoiding using a product that harms the environment, and desire to learn about contamination), outdoor skills (activities and strategies to survive into forest or similar ecosystems), wayfinding (ability to move effectively in unknown places, to read maps and to retrace one's path when leaving the main road), knowledge (familiarity to learn norms in work and new areas as well as renewable energies), practical skills (facilitate to create sites where feel comfortable and ability to make new friends and find places of interest) and resource conservation (activities to reduce energy and actions to use with the responsibility of resources as water, avoiding wasting its). To Pederson, this competence is because it supports our survival and adaptation as well as development.
- Pro-Environmental Competence (PEC): it is defined as the capacity to respond positively to the demands of environmental protection. This model is very similar to EC. However, the components are specified towards environment conservation (ecology) and not to personal survival of environment features. Knowledge and attitude are requirements to develop skills in the conservation environment (De Young, 1996). A study from Corral-Verdugo (2002) defined the following components: skill (activities about use and consumption of essential natural resources), personal motives (saving vital natural resources), cultural beliefs (available of crucial natural resources as water, support of science to solve the environmental problems and use of resources), ecological perceptions (consumption of essential natural resources by others) and conservation behavior (composting or reusing significant natural resources).
- Action Competence (AC): it is defined as three related concepts (Breiting and Mogensen 1999, Olsson et al., 2020). First, the knowledge of the impact of our actions: how these actions are significant to tackle complicated environmental problems, and how the realization of these actions will improve the situation in the future. Second, feeling self-efficacy about the importance of our efforts, choosing those more effective strategies, since now we know of them. It is important to emphasize that individual actions are converted into collective actions through our influence on others. Finally, the third concept is the willingness to act. These explain that to implement them, we need to know their effectiveness and make us feel good, providing us with a motivation for their realization. Do not forget that they are more efficient if we implement them together.

2.3.3. Definition of Climate Change Competence

Until now, several competences related to climate change exist. Nevertheless, none of them specifically addresses this phenomenon. And although it is already indirectly addressed in other competences, such as the eight key competences developed by the Council of the EU, it continues to have insufficient elements needed to deal with the climate crisis and therefore it is necessary to create a specific one to address it strongly and immediately, as according to the IPCC plan and the Paris agreement, which calls for reducing greenhouse gas emissions by half and in full by 2050.

Tobón et al. (2010) suggest that it should have these essential components such as:

- Formulation of the analysis of problems: The competence to be formed or assessed is described based on the analysis of contextual issues, seeking to have a performance verb, a conceptual object, a purpose, and a reference condition. This competence is defined as the ability to respond to the current emergency climate. It implies that system education gives effective communication about the science of climate change, correcting the misunderstandings surrounding this phenomenon, allowing us to connect with others. In addition, this competence allows creating citizens more interested in being more responsible with the planet, achieving to change their lifestyle, and accepting the policies and suggestions of scientists to guarantee the survival of humans and all species on the Earth.
- Criteria construction: These are the fundamental guidelines to be taken into account in the assessment of competence. The criteria seek to consider the different components of the competency (learning to know, learning to do, and learning to be), better known as knowledge, ability, and attitudes.

As we saw previously, Climate Change Competence (C3) could be defined as a competence, because it has two components explained by Tobon et al. (2010). The C3 involves recognizing the importance of education to increase awareness and responsibility on care for the planet through understanding the science of this phenomenon, as well as identifying the main human activities that are altering the balance of the climate system, achieving change in our lifestyle. All these are structured in the dimensions (knowledge, ability and attitude) and that as we will see below, it has a strong theoretical basis.

The C3 is composed of the dimensions and sub-dimensions that allow us to organize the topics around CC. The first is knowledge and has the following sub-dimensions, biophysical

processes, consequences, causes and adaptation and mitigation. The second dimension, called ability, entails purchases, transport and saving energy. Finally, the attitudes are formed by trust in the source information on CC, responsibility to act against CC and education support. We describe the structure of C3 as follow:

2.3.3.1. Knowledge

We are going to start explaining the first element. The knowledge on CC includes all concepts and contents related to this phenomenon as its definition, the magnitude of its consequences as an unbalance of the earth's climate system caused by humans.

The IPCC is the world's highest body assessing the science of CC. It is made up of 195 countries and thousands of scientists from all over the world in three working groups (WGs). WG I study the science of climate change. WG II deals with the social and economic aspects of CC, as well as its impacts and adaptation options. Finally, GW III studies the mitigation aspects, strategies to reduce and eliminate greenhouse gases. Periodically, these groups publish their reports, which bring together all the scientific research produced each year on the science of climate change, its impact on the planet, future scenarios and, most importantly, the most significant adaptation and mitigation actions. For all these reasons, it is considered the fundamental source for this dimension.

The United States Global Change Research Program (USGCRP, 2009) defines knowledge about CC, as “climate literacy”, a literacy focused on helping people understand the influence they have on climate, as well as the influence of climate on the individual and society. In this definition it is necessary to take into account both the physical and biological aspects of the problem, as well as those of a social and economic nature, which contribute to enhancing a certain type of representation of the phenomenon.

In this dimension, climate literacy plays an important role in this dimension. According to Dupigny-Giroux (2017), “climate literacy” has as an aim form to people with highly qualified scientists. This definition explains that having knowledge on CC can help to understand the reality of this phenomenon and therefore, the citizens can take decisions to improve their quality of life (García-Vinuesa et al., 2019). The previous affirmation is supported by McMillan et al. (2004), where high levels of knowledge on the environment make people have better ecological and high pro-environmental attitudes.

The National Oceanic and Atmospheric Administration (NOAA), the American Association for the Advancement of Science (AAAS), NASA (National Aeronautics and Space Administration), scientists and teachers in 2009, created The Essential Principles of Climate Science Literacy. The previous educational program was coordinated by United States Global Change Research Program (USGCRP) and suggested knowledge on CC should be classified on:

Biophysical processes are defined as the basis of physics and chemistry about the science of climate change (IPCC, 2013). The main concept that is necessary to understand this phenomenon is the greenhouse effect (GHE). GHE is defined in the glossary about "Climate Change 2013: The Physical Science Basis" as the infrared radiative effect of all components of the atmosphere that absorb in the infrared. Furthermore, NASA (2021) in its web page, adds that is a process natural and that allows the live on the Earth because keeps it warmer thanks to that the gases of the atmosphere retain heat from the sun. However, several studies claim that there is a misconception with this affirmation. Most people believe that the greenhouse effect is a process that inhibits the development of life on Earth (García-Vinuesa et al., 2019; Meira-Cartea et al., 2018). Biophysical processes also include Carbon dioxide (CO_2) as one of the main greenhouse gases (GHGs) responsible for CC. This gas is part natural of the atmosphere and is a greenhouse gas, an important heat-trapping gas (GHE) that is emitted through human activities (deforestation and the combustion of fossil fuels), as well as natural processes such as (respiration and volcanic emissions) (NASA, 2021b). The industrial revolution and current human activities have increased stable CO_2 concentrations from 280 ppm to 400 ppm from 1850 to the present respectively (Farmer & Cook, 2013; IPCC, 2014a; NASA, 2021b).

Consequences include the negative impact on earth and human life (IPCC, 2014a; USGCRP, 2009). It's important that people know the effect of our actions on the climate system as the land, oceans and atmosphere. Within the consequences there are also misconceptions that most people have. For instance, many people believe that the CC is a consequence of the hole in the ozone layer (Meira et al., 2013; Nyarko & Petcovic, 2021). A study in Spain reported that 8 out of 10 citizens believe in this affirmation (Meira Cartea, 2015). One of the greatest reported consequences of CC over the last 50 years is the increase in extreme weather and climate events (IPCC, 2014a). For example, most of these changes have been associated with human influences, such as decreasing cold temperature extremes, increasing warm temperature extremes, rising sea level peaks, and more intense precipitation in various regions (IPCC, 2015).

Causes of CC are produced by human activities (USGCRP, 2009). There is currently a scientific consensus (more than 97%) that current temperatures are due to human activities (Cook et al., 2013, 2016). This is mainly due to the increased consumption of fossil fuels, causing an increase in greenhouse gases. In addition, the consumption of fossil fuels, the reduction of forest cover, and the rapid expansion of agriculture, population and economic growth (generating more industrial activities), also release carbon dioxide (IPCC, 2014b).

Responses to CC, better called mitigation and adaptation. Other researchers name this sub-dimension as action-related knowledge about climate change Seroussi et al. (2019). However, as they are one of the most significant parts of the CC fight, they will be treated here in a conceptual way. For instance, Arto-Blanco et al. (2017), García-Vinuesa et al. (2019) and Meira et al. (2013) propose activities such as meat consumption, creation of carbon sinks and consumption of fossil fuels as response activities from the point of view. It should be remembered that the IPCC created the interdisciplinary working group III, which is in charge of designing and assessing a large number of significant activities to combat CC. Therefore, they will be discussed in detail in the abilities dimension.

The previous sub-dimensions are supported also by research made by educator's academics as García-Vinuesa et al. (2019), Meira-Cartea et al. (2018) and Nyarko & Petcovic (2021). Similarly, Seroussi et al. (2019) have classified the knowledge on CC in the same way.

According to USGCRP (2009) the previous sub-dimensions, allows that a person:

- Understands essential concepts about climate.
- Assesses climate information received.
- Shares scientific information with others.
- Is aware of personal actions that affect the climate.

To summarize, the knowledge on CC includes all the elements that explain the science of this phenomenon, how it affects the survival of humans and all species on the planet, and what we can do to address it. This knowledge should be explained by experimental science such as physics, chemistry, biology, geology, mathematics, and technology. These sciences allow understanding the climate system's functioning, applying the scientific method necessary to determine the severity of this phenomenon, and knowing the possible future scenarios if we do not change our lifestyle. Nevertheless, the human sciences such as economics, politics, law, sociology, health, and in general all those that deal with the functioning of societies are also necessary, since these are

the ones that help us to make collective decisions, as well as to have knowledge about the consequences of human activities on the climate and the global magnitude of the problem. Likewise, health sciences explain how this phenomenon affects our body and the different ways to reduce diseases such as malaria, diarrhea, and heat stress. All this allows us to understand and describe the relationships between the physical and social worlds, so it is necessary to treat the phenomenon as a multidisciplinary problem.

In conclusion, this dimension has the objective to improve the knowledge on biophysical processes such as the greenhouse effect and many other related phenomena that do not understand it (Seroussi et al. 2019). Likewise, causes and consequences present misunderstandings in the teachers (Liu et al, 2015).

2.3.3.2. Ability

Ability is defined by the European Commission (2018) as the capacity to use knowledge and obtain results desired. Schola Europaea (2018) include the development of skills to resolve problems and address the changes in the society of today. Within the context, the ability of C3 concerns the personal actions we can take in our daily lives to deal with CC reducing greenhouse gas emissions (Gifford & Comeau, 2011).

Furthermore, its creation is supported by the Organization for Economic Co-operation and Development (OECD), which emphasizes the need to create new abilities and skills to adapt and face the new challenges of the 21st century, such as CC (OECD, 2019). According to OECD, these new abilities need to be developed in all education levels from early childhood education until university. As could be seen previously, OECD (2018) the abilities are defined as the capacity to use the knowledge acquired in a specific issue (in this case CC) to obtain desired results.

The IPCC WGs II and III deal with Adaptation and mitigation are the main tools that we have to deal with this problem. These are strategies that look to reduce the emissions and concentrations of GHG into the atmosphere, the mitigation has the objective to reduce the damage of the existing CC. These strategies can be applied almost in all human activities to reduce the anthropogenic effect on the environment. The abilities in this competence are closely related to these concepts and can be classified in individual and collective actions. As parts of this dimension this group proposes: energy, transport, buildings, industry, waste management, agriculture, forestry, and other ways of land management (IPCC, 2014b).

According to Gifford & Comeau (2011) ability dimension is called "Behavioral intentions". They classify it in residential or household action and transportation behaviors.

However, from an educational point of view, and from the role of teachers, this dimension is structured in personal actions that can be replicated to become collective actions. It was elaborated through the opinions of scientists who participated in the development of seminars in 2019 at the University of Salamanca, among them: Francisco Heras (Spanish Climate Change Office (OECC) and Ministry of Ecological Transition) and Fernando Valladares Ros (Spanish National Research Council (CSIC)). In addition to the review of several studies (Bain et al., 2016; Gifford & Comeau, 2011; OECD, 2018; Sahin et al., 2012; Whitmarsh & O'Neill, 2010). Therefore, ability dimension of C3 are entails by the sub-dimension as follow:

Purchases better called "eco-shopping" (Whitmarsh & O'Neill, 2010). The consumption of products has a large impact on the carbon footprint so it is important to select those that are more eco-efficient. This sub-dimension includes activities related to selecting and consuming local, energy-efficient and seasonal products (Bain et al., 2016; Gifford & Comeau, 2011; OECD, 2018; Sahin et al., 2012). By doing these activities, such as consuming local and seasonal products, we avoid producing products that require heaters or refrigeration to produce them. Likewise, when we select organic products, we favor their production, generating care for the soil. Therefore, we do not reduce its capacity to capture carbon as much as with traditional techniques, saving the energy cost of producing fertilizers and pesticides.

Transport better called "eco-driving" (Whitmarsh & O'Neill, 2010). Includes the most effective actions to reduce fossil fuel consumption (Bain et al., 2016; Gifford & Comeau, 2011; Sahin et al., 2012; Whitmarsh, 2008). To give an illustration, replacing short urban transport with public transport or other alternatives can reduce the carbon footprint by 0.6 to 1 tonne of CO_2, as well as sharing private transport with someone else by 0.3 tonnes of CO_2 on average (Kawamoto et al., 2019).

Energy Saving actions or known as "energy conservation actions" as well (Whitmarsh & O'Neill, 2010). This part of the ability contains personal activities that we can do from home and that aim at a responsible use of energy consumption (Bain et al., 2016; OECD, 2018; Gifford & Comeau, 2011; Sahin et al., 2012). Unfortunately, we use energy in our homes in order to live more comfortably. For example, in Europe, more than half of all homes are heated (European Commission, 2021). Thus, we have to fight not to waste so much energy (detect which parts can

be worse insulated and reinforce them, with this measure we reduce 0.9 tons of CO_2 on average (Feist et al., 2005)) or not to consume energy sources that emit CO_2.

As see, the role of the teachers is essential to improve abilities on the citizens, because once they understand the science of CC, they take a keen interest in this phenomenon (Ekborg & Areskoug, 2006) and begin to act against it (McNeal et al., 2017) such as influence in others.

Overall, abilities emerge once the science of climate change is understood. Ability includes the skills to mitigate and adapt. For this, it is necessary to involve all the activities related to reducing greenhouse gas emissions. To achieve it, we must encourage and influence others, communicating with them how to decrease our carbon footprint with simple change into the lifestyle. For example, avoid using the car, always carpool, if possible, walk or use public transportation. Another example is to reflect on our lifestyles and our choices as consumers, choosing sustainable products from the surroundings. The abilities to distinguish different types of energy sources, making appropriate use of them and recognizing its impact in the ecology of the planet.

2.3.3.3. Attitude

Defined as the evaluation by the degree of being in favor or against an entity and its actions (Eagly & Chaiken, 1993). UNESCO (2015a) designates this dimension as “Socio-emotional” and is defined as a concept related with values, such as responsibility, respect, solidarity which should be shared. According to the European Commission, (2018a), attitudes include the willingness and mentality to act or respond to ideas, people or circumstances.

Therefore, after understanding a phenomenon, attitudes will be formed that will strengthen or weaken the abilities related to addressing it (Ajzen, 2002). In this sense, being informed about CC, understanding that this phenomenon is caused by human actions, will allow us to evaluate actions against it. Attitude dimension is a very wide dimension, which contains a lot of content. However, on the basis of the literature review made in different countries like Australia and Great Britain (Reser et al., 2011), Spain (Meira et al., 2013) and the United States (Feldman et al., 2012), and research carried out by specialists in attitudes towards CC, we have selected three elements called sub-dimensions:

Trust per agent This sub-dimension is related to the trust in the message provided by different sources of information. Resnik (2011) explains it in five different aspects. First, trust

enables collaborative social interactions. Second, trust creates legal and ethical obligations. Third, trust is a relationship between individuals. Fourth, trust implies the assumption of risk. Finally, trust is acquired by previously demonstrated by past actions and performance.

Once its definition is understood, we can say that it is an important element in the acquisition of content (Valdez et al., 2018). The information received by agents determines the reorientation of guidelines that will help to address CC (Gonzalez-Gaudiano et al., 2014). On other hand, the trust influences people to act because they make the people search information and acquire skills to mitigate, increase the risk perception (Seebauer & Babcicky, 2018). According to Cardwell (2011), the trust in the sources of information facilitates the understanding of CC.

Teachers, ecologists, important organizations such as the UN, scientists and media are identified as favorites to achieve this task (Boon, 2014; Rajeev Gowda et al., 1997; Reser et al., 2011) because they help in facilitating an understanding of complex scientific findings. For instance, teachers are some of the most trusted suppliers of scientific information to the public because they can take an important role in the education of the citizens on the basic science of CC (Rajeev Gowda et al., 1997). Within this context, a more recent study showed that 2 out of 3 Spaniards trust in the information about CC given by teachers (Meira et al., 2013). This high confidence may be due to the fact that teachers have strong levels of concern for future generations, believe in the power of education to cause action and have high levels of belief that humans are the main cause of CC (Nation & Feldman, 2021). Ecologists are one of groups with high trust to citizens, the reason is since they apply effective actions to mitigate (Seebauer & Babcicky, 2018). Media such as television and newspapers are the principal agents to give information to Americans because more than half of them are informed by these agents (Feldman et al., 2012; Moser & Dilling, 2007). Likewise, Liu et al., (2015) argued that the majority of students learn more about CC through the media than in school classes. Scientists are another favorite group, since the people have confidence in the work they perform, such as policy-makers that they propose are based on their findings and that are accepted by most of the society (Myers et al., 2017). In this same vein, Almassi (2012) showed that the attitudes on CC depend primarily on the confidence of scientists since most people have little first-hand knowledge about this phenomenon. Additionally, Almassi (2012) indicated that the individual actions can be strongly influenced by the credibility of the group conducting the research and the CC stakeholders and journalists who interpret and communicate the results to the public. Finally, large institutions or organizations such as NOAA

and UN towards IPCC, count with much confidence because they are dedicated to finding solutions to problems and thus support their policies (Arbuckle et al., 2015).

Therefore, knowing how these agents can motivate citizens is crucial, since effective communication promotes the development of social changes that are desired (Moser & Dilling, 2007). Additionally, CC is an issue that has had high disinformation campaigns (Kolmes, 2011) thus these groups have an essential task to combat it.

Responsibility is related to what actors or agents are more responsible for this crisis. This is essential to act against CC is a part essential to attitudes. According to Fragnière (2016) responsibility is defined in two ways. On the one hand, being responsible means that one may be held culpable or otherwise responsible for a certain state of things. On the other hand, responsibility refers to what a person should do. In this sense, both concepts are defined by climate ethics. Several authors seek to determine whether people can be held liable for damages due to their past and current GHG emissions, while others wonder whether people have responsibility to reduce and abstain from emitting GHGs. However, other authors as Prellegrino (2018) establish that responsibility can be deal in climate settings towards in the follow perspectives: on the one hand, "equity", where to avoid CC damage, participation in collective efforts is required (Baat, 2014) and on the other hand "disociation", individual responsibility is part of a collective responsibility, whereby individually produced GHGs are part of global emissions (Nolt, 2011).

Nevertheless, to study responsibility, from any of the previously mentioned points of view, IPCC (2014b) argues that we must all mobilize against CC. In addition, as we can see in the figure 2.5, the Working Group II of IPCC in their Fifth Assessment Report established that actions to address CC are distributed on international institutions, national, regional and local governments, as well as the family and on a personal level.

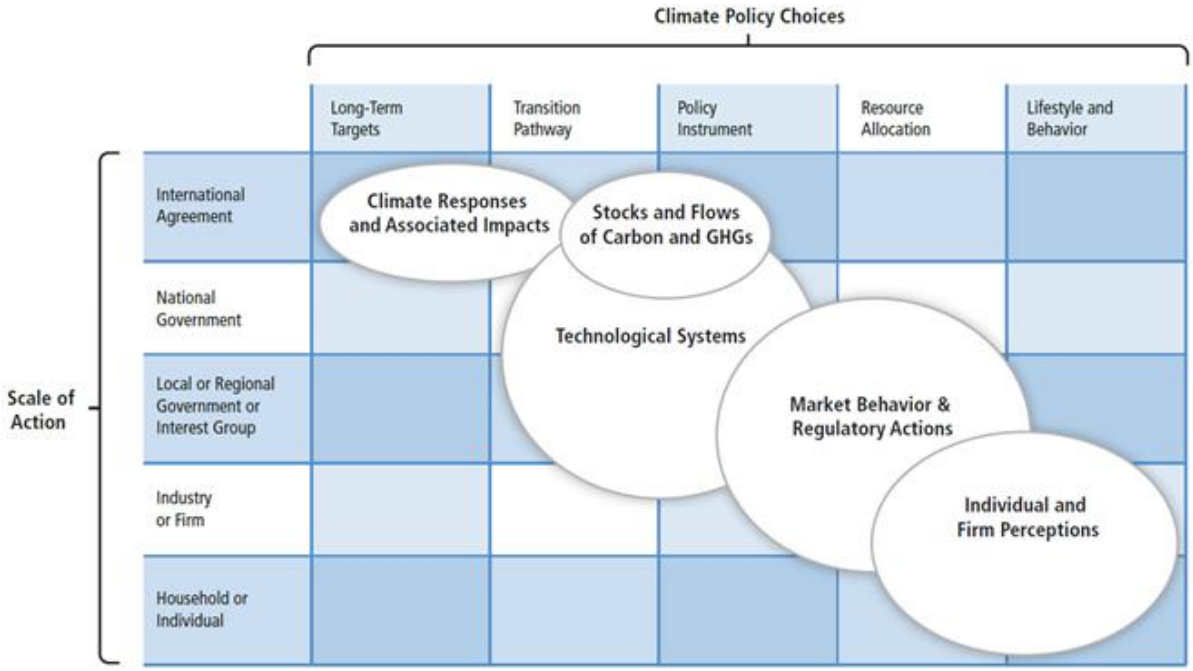

Figure 2.5. *Scale of action to address CC. Reference: Chapter II of Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

Within this context, UNESCO supports Responsibility to act against CC through ESD, which have been progressively becoming part of local, national and global policies to cope with sustainable development challenges such as climate change (Rieckmann, 2017). Moreover, UNESCO has created Global Citizenship Education (GCED) to cope with challenges to improve sustainability, which train students to understand that these problems are local and global (UNESCO, 2015b).

Similarly, the European Commission (2018a) through the eight key competences, for example, in the civic competence, states that problem solving (such as CC) is of personal, local, national and European interest. Therefore, all students should be able to participate at all the levels mentioned above, especially in sustainable development issues (Schola Europaea, 2018).

Likewise, the OECD (2018) introduced the new OECD Global Competence, which was tested in The Programme for International Student Assessment (PISA) tests that year. This competence is defined as the ability to discuss local, global and intercultural concerns to promote mutual well-being and sustainability.

Unfortunately, there are people like Sinnott-Armstrong (2005) that think that taking responsibility for CC should not be tackled by individuals but only by governments. A study showed that most citizens believe that national governments, the international community and large business have a greater responsibility (Reser et al., 2011). As suggested by several authors, the reason for this is because the people transfer part of their responsibilities in solving problems to their political leaders. Therefore, there are already many working on the task to change that misconception, turning the task of climate change into a collective action. For instance, Wamsler & Brink (2014) propose:

- Mayors should provide information on individual and collective measures to act and encourage them. This will bring individuals to collaborate with mayors' offices. For example, in Salamanca, a city in northwest Spain, the city authorities have designed an advertising campaign where they emphasize on their website that by doing this action, we all win, we combat climate change by introducing nature into the urban environment and we obtain benefits such as biological pest control and improve the aesthetics of the city (Salamanca City, 2021).
- Motivate citizens to take action through incentives (subsidies for those who do major actions) or disincentives (taxes for those who engage in maladaptive behavior).
- Mutual dialogue between citizens and authorities through events where citizens can contribute ideas and discuss local issues. by considering citizens' opinions and suggestions, citizens will increase their engagement.

Contribution through education, includes how climate literacy is empowered through the education system. In addition, awareness and participation for action will be achieved if citizens have high levels of climate literacy, which is crucial for improving education and training on this issue (United Nations, 2016). This sub-dimension explains that it is necessary to create a new competence that starts from teachers. One of the advantages of creating a specific competence to tackle this phenomenon is that education personnel are familiar with this strategy "competence". Furthermore, according to a study by Fuertes et al. (2021), more than 90% of the teachers expressed that the best way to deal with CC in education is through competence. Similarly, research by Karami et al. (2017), showed that 1 in 2 teachers stated that it is crucial to understand the science of CC through education. Likewise, most students believe that increasing environmental or CC content is among the most effective ways to act against this phenomenon (Lehnert et al., 2020). In

the same vein, a study applied to pre-service teachers displayed that most of them agree that it is necessary to reinforce educational laws on pro-environmental issues (Pe'er et al., 2007).

Hence, C3 is an alternative way of dealing with a concept that is difficult to understand. However, in order for C3 to be properly implemented, it is necessary for teachers and trainee teachers to have the didactics for teaching CC (Lopera Pérez & Villagrá Sobrino, 2020). Therefore, it is necessary to increase the training of pedagogical content, since most teacher training centers do not yet include it (Sureda-Negre et al., 2014).

In sum, the attitudes include all values related to living beings' survival and well-being, climate justice, the global dimension of the crisis, and the need to respect nature and the environment. It also involves accepting policies, understanding that coping CC is the task of everyone and not only to large institutions, and suggestions elaborated by scientists and educators to mitigate this phenomenon and the need to respect nature and act in a quick, informed, and coordinated manner to face it. Moreover, the teachers should appreciate the importance of introducing their class content about tackling climate change, improving the willingness to understand the impact of personal activities and how these are converted into collective.

2.4. Tools and Learning programs

Currently, there are several tools and didactic strategies to include CC into education. For example, there are educational games based in CC, such as escape rooms and role-play simulations. Furthermore, there are other strategies such as virtual field trips and MOOCs. All these tools are explained below.

Climate change games defined by Wu and Lee (2015), as games in which students simulate the role of the human system and the possible implications on this phenomenon. These tools aim to ensure that scholars learn to respond, be concerned, and understand climate topics. The wide variety of formats such as mobile games, computer games, card games, and pervasive games makes them favorite teachers. However, most of the research in these tools does not include those games where climate change is not a central issue, such as simple footprint carbon calculators. Another instance of gamification based on climate change education and that is designed for teenagers is escape rooms. These new interactive tools consist of achieving escape to a real-life (or virtual) room. For this, students count on a time limit to complete several challenges (Ouariachi & Wim, 2020). The most common structure of escape rooms consists of receiving a reward after giving a solution that could be hidden and should be found while gamers

are playing. The main benefit offered by the escape room is that it could be considered a complete classroom learning topic about climate change since it is designed to stimulate the mind and provide problem-solving (Wiemker et al., 2015).

Furthermore, a study made by Ouariachi & Wim (2020) affirmed that students improved their knowledge and awareness on responsible, sustainable activities after participating in escape rooms with a climate change central topic. Nevertheless, it must recognize that strategies present difficulties, such as achieving full-scope coverage of the climate change issue, because escape rooms are limited in time and reach. Therefore, Role-play simulations (RPSs) adapted to education are another interesting tool for tackling climate change. In this context, in Rumore et al. (2016), every participant assumes the feature of a character, developing a story with dialogues, where participants make decisions and perform actions without a guide to follow but reflecting the real world and scientific knowledge. The main advantages of RPSs applied on climate change contents are that the participants increase scientific vocabulary and its influence on the decision-making based on knowledge about this phenomenon (Stokes & Selin, 2016). In addition, it improves the capacity to find collective solutions to problems presented on RPSs.

Other academic educators have embedded interesting learning strategies such as virtual field trips held through Virtual Reality. These novelty pedagogical strategies are defined as an illusion of a three-dimensional field interactive and replicate a diverse range of real-world elements utilizing audio and visuals (Schott, 2017). Virtual field trips aim to achieve fieldwork assignments, simulating nature, where the participants are avatars and can collaborate and communicate in the environment. Many studies have shown that pedagogical strategies like these provide, through visualizations and sound, an increase in awareness and engagement towards the environment. For instance, Petersen et al. (2020) conducted a study with their students. They tackled the consequences of climate change through virtual field trips to Greenland, where the students could observe the impact of high emissions of carbon dioxide in this zone. As a result, students showed an enhancement of knowledge and interest in climate change. In addition, the students showed a lifestyle change, with an increase in actions related to consciousness in their everyday life and a better self-efficacy on the realization of their activities.

2.4.1. MOOCs as educational tools

Previously several studies about strategies, pedagogical, and learning tools applied to tackle climate change have been discussed, such as games, escape rooms, role-play simulations, and virtual field trips. Nevertheless, all of these are used only to formal education and lack structure to

hold the main topics on climate change. Those are why we are going to argue widely about the importance of Massive Open Online Courses (MOOCs) and their deployment on the education system as an alternative more efficient way to tackle climate change. Currently, MOOCs give the possibility to assist the need for formal and non-formal learning. These valuable tools usually are offered by platforms such as Coursera, Edx, Udacity, FutureLearn, and MiriadaX. In this way, MiriadaX considers four main elements of these educational tools:

- Present information about a particular topic with advanced knowledge that generates tremendous interest in the people.

- With a homogenous basic Structure, with a duration of four to six weeks, with one thematic module every week.

- Attention to communication, establishing ways to communicate between teacher-student and student-student. It is recommendable to inform participants about the tools used. These could be synchronous (skype or google meet), asynchronous (forums and social networks), or a combination of both.

- Finally, Team. The tasks developed during MOOC are distributed among the members. MOOCs are defined as a virtual training system that is already present in the current educational panorama and responds to a determined understanding of e-learning (Mengual-Andrés et al., 2015).

Furthermore, according to Marco-Cuenca et al. (2010), MOOCs present four main features:

- Massive: MOOCs are designed for a significant possible number of people. The potential number of participants must be unlimited and have a global reach.

- Open: MOOCs must be accessible from everywhere, and every time, free status has been associated with them, with no participation or credit charges and no registration cost. There are no prerequisites for participation, and registration is free.

- Online: MOOCs are considered distance learning courses, whose channel is the Internet, allowing access and participation to any person with a connection. In addition, as was mentioned previously, these courses are supported on different social network platforms. Students work together in an open and participative environment, and their shared interests link them but with a fundamental level of autonomy in their learning.

- Courses: MOOCs are assumed as a set of activities that require monitoring over a given period with readable content, completed and structured. As courses, MOOCs should count on teaching objectives and assessments to accredit the knowledge acquired. Therefore, learning evaluations have been considered necessary for the student to interact and self-evaluate the learning achieved.

These beneficial features that MOOCs offer are currently being used as practical tools for training on climate change. For instance, The UN has created a unique platform called UNCC: Learning to offer support to countries to achieve actions against climate change through education. This platform counts several MOOCs, such as Climate Change: From Learning to Action, Climate Change, Peace and Security, Introductory on Climate Change, Fundamentals on REDD+ (this a framework which term stands for "reducing emissions from deforestation and forest degradation, conservation of existing forest carbon stocks, sustainable forest management and enhancement of forest carbon stocks"). Some of these are adapted to countries' specific needs, such as Green Transition in Eastern Partnership Countries and Sustainable Consumption and Production in Africa. Evaluation is an essential part of these tools are represented through quizzes, which participants have to resolve after completing every module. Of course, the participants have to pass every exam with a score above 70% to receive the certificate.

In this way, to date May 2021, 335 MOOCs have been elaborated on studying climate change topics from different fields, such as Technology, Communication, Business, Geography, Health, Politics, Economics, and so forth. The distribution of these MOOCs by other platforms is 56 in FutureLearning, 160 in EdX, 107 in Coursera, and 12 in MiriadaX.

In addition, several of these MOOCs are more specific and tackle this phenomenon from education. For instance, there are MOOCs specialized to educators of all levels of the educational system, where the main topics are: What teach about climate change? How to teach climate change from the classroom? Which learning resources can use? How to raise awareness among students? All these questions and others are answered in the following MOOCs:

- Teaching Climate Change: Offered by FutureLearning. This course has been developed by STEM Learning and UK users. During three weeks, the teachers learn basic science on climate change and how to engage students in using resources from the European Space Agency (ESA) and others similar? In addition, the participants on this course learn to develop climate science projects with their students, identify local problems on climate

subjects, attempt to solve them, and compile data on climate change to analyze with the students.

- Climate Change Education: Supplied by EdX. Inter-American Development Bank (BID) has elaborated on this course. During ten weeks, the participants learn to use online games with their students and make use of resources created by the professionals that participated in the elaboration of this course. Furthermore, the teachers learn to develop projects in their schools, applying the different ways shown on this course to mitigate this phenomenon. This course has been a great success in Latin America.
- Awareness and training on climate change for primary and secondary school teachers: Offered by MiriadaX. Salamanca University has developed this course. It has had two editions, and more than 1,800 participants have taken it, mainly from Spain and Latin America. The participants learn about the physics and chemistry of climate change and the causes and consequences of this phenomenon. In addition, this course answers what we can do from education. For this, participants study mitigation and adaptation strategies and an analysis of primary and secondary taught curricula.

2.5. Assessment of climate change competence

As we saw previously, C3 involves recognizing the importance of education to increase awareness and responsibility on care for the planet by understanding the physics and chemistry of this phenomenon, as well as identifying the main human activities that are altering the balance of the climate system, achieving change in our lifestyle. All these are structured in the dimensions (knowledge, ability and attitude) which have a strong theoretical basis.

Once the need for the creation of the C3 is known, in addition to its structure, it is necessary to create an instrument that will allow us to evaluate it, provide us with information on its functioning and development, and determine its behavior in different populations. Moreover, its application will allow us to create efficient strategies with few resources and advance in developing and improving C3.

To this end, we have created a questionnaire that serves as a tool to evaluate C3. We have named this questionnaire C3-Q. A selection of questions will always partially assess all the elements of an extensive competence. Therefore, our selection of questions is made concerning the particularities of the group in which the instrument has been applied.

Once the C3-Q has been created, it must be tested in different populations to analyze its behavior. Since the construct is born from education, it is advisable to start determining the C3 from the main actors, such as teachers in training, both primary and secondary, and teachers already in service at both levels. This allows us to know how C3 behaves in these populations. We have also planned to test it by applying a pre-experimental design to verify whether it is possible to improve it through interventions such as MOOCs. For this, we will use two versions of our courses, "Climate change awareness and training for elementary and secondary school teachers" and "Science of Climate Change". As both different cover populations, we will be able to analyze their behavior by studying the different socio-demographic variables, such as age, gender, type of teacher by level (elementary and secondary), teachers in training or in service, teachers, and non-teachers, and region (Spain and Latin America). In addition, we will analyze the relationship between its elements (knowledge, abilities, and attitudes) to verify if they are associated; therefore, to understand how the improvement of each of the parts influences the others.

All these processes will allow us to have a better vision of its nature. In addition, we recognize that although the C3-Q attempts to unite all the elements of C3, this tool cannot cover all its parts because it is so broad and interdisciplinary. For example, we know that this is one of its broadest elements in attitudes, so we try to ensure that it contains essential values such as responsibility and trust. However, we recognize that it could be modified for improvement or adaptation to other populations. Therefore, we do not rule out the possibility of including new items or modifying some of the current ones in future research.

The C3-Q provides an overview of the benefits that education can provide through learning environments that encourage teachers to relate QC science to their subjects and students' daily lives. It also gives them the confidence and security to deliver that content from a socio-scientific perspective to develop C3 in their students and society as a whole. Therefore, the main objective of the creation of the C3-Q is to support and improve the insertion of CC contents, as well as its teaching, its evaluation and to provide a response of the educational centers to the challenge of CC in order to prepare today's youth to be tomorrow's sustainability leaders.

7. Chapter VII. Conclusions

7.1. General conclusion

The novelty of our work is the introduction of CC in education. As we saw, there are currently not several strategies that develop this thematic. Our proposal to do it through C3 seems to be a complete and coherent strategy to do it. Furthermore, the C3 demonstrated recognition of the importance of education to increase awareness and responsibility for caring for the planet through understanding the science of CC. The dimensions (knowledge, abilities and attitudes) of C3 have a solid theoretical basis. Furthermore, the introduction of CC to education is essential. Our findings offered a novel perspective.

We have found that associating it with an assessment tool such as the helps identify phenomena and propose tools for improvement. The C3-Q is a good assessment tool, and it allows us to evaluate the C3 competence from a social, economic, and educational perspective, studying it through the three connected dimensions. Other instruments as competence in sustainable development do not allow us to determine specific aspects related to the urgent climate crisis. Moreover, although scales such as determining attitudes towards greenhouse gases exist, these continue to evaluate performance superficially. In addition, C3-Q has been tested in different populations with a variety of age ranges, in both genders, from regions of Spain and Latin America, and in different professional groups, although mainly from the educational field. Moreover, it was shown that the elements of C3 are positively associated and that an improvement in one of its elements, such as knowledge, is a predictor of attitudes and abilities. As we saw, MOOCs are an alternative learning tool to improve C3 performance.

Furthermore, groups of individuals deficient in C3 elements can probably be improved through these courses. In addition, more and more, these courses are positioning themselves as a tool to educate and inform the population on issues related to sustainability, environment and CC. As mentioned above, these courses can be a powerful way to obtain data that allow us to conduct research such as the one offered in this thesis.

7.2. Specific conclusions

This chapter shows the results of the complete development of the project "Implementation of MOOCs as a tool for the improvement of Climate Competence for Elementary, Secondary and Pre-services School Teachers". The main findings are described and have been distributed in

chapters. In them, the introduction of educational research as an alternative to deal with CC from education was evidenced. Also, we explain the creation, design and validation of an instrument as a tool to test its evaluation in the population. In addition, the methodology implemented to achieve this and how it worked with the sample used is presented in general terms. We also describe the strengths and weaknesses we found throughout the project as follow:

- In Chapter I, we described the reasons that motivated the realization of this thesis project. The climate crisis requires great efforts, and education should be one of the key tools for mitigation and adaptation. Nevertheless, to reach this goal, there are several obstacles. As noted, there are many. However, among them is that, although it is recognized that education is indispensable to fight CC, there is no concrete strategy of how to introduce this phenomenon to education. Another obstacle is that PSTs and ISTs present many deficiencies on issues related to this phenomenon and its science and didactics. Many ISTs are not motivated to teach or have problems in doing so.

- In Chapter II, the climate change competence (C3) was established as an educational strategy to introduce this phenomenon in education. For this purpose, the knowledge, abilities and attitudes on CC that PSTs and ISTs should have been identified. Among the knowledge of CC these should include understanding the phenomenon, its causes, consequences, and general measures on adaptation and mitigation to this issue. As for abilities, these include a series of personal actions that we execute from our home or work and actions associated with the way we mobilize ourselves. Finally, attitudes include the fundamental role of education as a tool to face this phenomenon. Moreover, it was determined that it is everyone's responsibility to fight against this issue and the importance of having confidence in the information provided by the different agents. To develop the elements of C3 in PSTs and ISTs, MOOCs were proposed. These learning tools show several advantages, such as global reach, free access, and the creation of a motivating climate with people with a common interest.

- In Chapter III, an instrument called C3-Q was designed to assess the elements of C3 in PSTs and ISTs. As we have seen, assessment tools are essential if we are looking for major social transformations quickly and with limited resources since they allow us to evaluate the starting point and correct the strategy of educational interventions to be more efficient. For this purpose, four models were tested in each of the C3 dimensions. The

bifactor model was the most appropriate model to represent the evaluation of C3. Because it presented the best indexes (absolute, incremental, parsimony), this model allows us to study the elements of C3 utilizing independent scales. In addition, the bifactor model gives us the advantage of analyzing the C3 items in two ways. In a general way, i.e., through its dimensions (knowledge, abilities and attitudes) or in a more specific way by studying its sub-dimensions. This is interesting, as we could evaluate at a general level each dimension of C3 independently or analyze the elements of each dimension. Therefore, this allows us to identify which ones are deficient and thus design proposals for their improvement or increase.

- In Chapter IV, the relationship between each of the dimensions of C3 was evaluated. These correlations can be helpful to understand behavioral phenomena in the face of CC or inform about which are the best educational strategies and what balances and compromises are possible in C3. For this proposal, all elements of C3 were described as having moderate and positive correlations. This allowed us to evaluate the existence of mediation analysis. It was determined that knowledge possibly positively affects attitudes and that these are reinforced to affect abilities positively. This allowed us to verify the indirect effect that knowledge has on abilities through attitudes. In addition, the direct effect of knowledge on abilities was analyzed. However, when analyzing the moderating effect of attitudes on these two dimensions, we were able to verify that attitudes do not moderate the relationship between knowledge and abilities. This could be explained by the existence of a moderate correlation between knowledge and abilities. Both analyses showed us the importance of understanding the science of CC since this is a predictor of attitudes and mitigation actions against this phenomenon.

- In Chapter V, we evaluated the elements of C3 in primary and secondary PSTs and ISTs. For this purpose, we compared the levels of knowledge, abilities and attitudes of primary and secondary PSTs and ISTs. We determined deficiencies in the knowledge dimension, in particular, that primary PSTs and ISTs have low levels of understanding about the science of CC. This lack of understanding about this phenomenon occurs especially about biophysical processes, consequences, and adaptation and mitigation activities. However, the last one was not significant in primary school ISTs. Regarding abilities, again, primary PSTs and ISTs show low levels compared to secondary PSTs and ISTs. These differences occur in mitigation actions related to shopping, especially in preference for local and

seasonal products and ecological and sustainable products. In addition, it was identified that these differences also occur in activities related to mobilization and transportation. Thus, secondary school teachers possibly prefer to move around using public transportation, walking, or avoiding private cars. In terms of attitudes, no differences were shown between PSTs and ISTs. This chapter also differentiated the levels of the C3 items in the PSTs and ISTs of the secondary study area (social sciences and experimental sciences). The PSTs and ISTs of experimental sciences presented a greater understanding of the science of CC. Especially in the biophysical processes and consequences of this issue. Regarding abilities, it was identified that PSTs and ISTs of secondary social sciences showed better levels in actions related to transportation than those of PSTs and ISTs of experimental sciences. Again, no differences were observed in terms of attitudes between the two types of secondary PSTs and ISTs. The trust that exists in the information offered by the different agents about CC science was also analyzed. It was found that PSTs and ISTs show distrust of the information offered by the media. However, scientists are the most trusted group to receive information about everything related to this phenomenon.

- Chapter VI was divided into two parts because we tested the performance of C3 through a pre-experimental design in two MOOCs with different audiences. In part A, we evaluated the importance of the MOOC "Climate change awareness and training for elementary and secondary school teachers" as an alternative to improve C3 in participants who were professionals in education and other areas. As a general result, we can affirm that MOOCs are a valuable tool to improve C3 in almost all its aspects. In addition, the assessment tools allow us to see in detail how competences improve in different groups or profiles. In this study, people from more than 24 countries participated, most of them from Latin America and Spain and people of all ages. Therefore, we describe the importance of these courses as a C3 improvement tool. It was shown that these learning alternatives are likely to improve all elements of C3, including all its sub-dimensions. Except for responsibility, which had a result very close to being significant. Given the variety of the sample that participated in the study, we decided to make different comparisons. Teachers showed an improvement in all items of C3. However, professionals not involved in education only improved in the knowledge dimension. We also compared C3 performance across the course by region. We found that people from Latin America probably have better abilities and attitudes than people from Spain.

However, in knowledge, people from both regions present equal levels. Finally, the dimension related to actions to mitigate CC was compared by age groups. It was shown that people aged 20 to 34 and over 65 probably perform better in abilities than people aged 35 to 64. Part B tested C3 in the MOOC "Climate Change Science", in which only ITs from Castilla y León participated. An increase in the knowledge and abilities of C3 was demonstrated in the ISTs after taking the MOOC. In terms of knowledge, the improvement occurred mainly in biophysical processes and consequences. Regarding abilities, an increase was observed in all sub-dimensions. As for attitude, there was a significant improvement only in the educational support sub-dimension. Although the other sub-dimensions showed improvement, these were not significant. However, overall, attitudes showed a significant improvement. The C3 items were compared in males and females. Males presented a better level of knowledge before starting the course. However, only females presented an improvement after the MOOC. As for the dimension related to mitigation actions, both improved. However, those men were close to being considered significant. In terms of attitudes, both presented improvements.

7.3. Limitations

There are several limitations to the current study. From the point of view of the design and validation of measurement scales, the instrument created used a sample of Spanish-speaking regions (Spain and Latin America), so we do not know whether the results obtained would behave in the same way with another population. The sample size was medium, with an *n* greater than 500. Although the number of items in the instrument is in accordance with the sample size, a larger sample is required to create a standardized instrument for the Spanish-speaking population. As for the studies related to the ISTs, the sample used was only of teachers from Castilla y Leon. As for PSTs, the sample was entirely from the University of Salamanca. Therefore, the results could not be extrapolated to the population of ISTs and PSTs in Spain.

Attending another limitation related to the sample, we found that some of the sizes of the groups were not balanced. For example, the sample size of women was three times larger than that of men. This is since the educational population is mainly made up of women. Another group with unequal size was among the ISTs' educational levels, and the Elementary teacher population was twice smaller than those of secondary ISTs. However, we applied robust techniques to identify differences between these groups.

Moreover, finally, another group with heterogeneous size was that of age, and we found a very small sample of teachers over 65 because most are retired at that age. Another limitation related to the sample is how to obtain it. We used a non-probabilistic sampling technique, specifically by convenience.

In relation to the methodology used, the main limitation could be the lack of a control group. However, the use of the pre-experimental design in social sciences is a valid design. Another deficiency related to the methodology is that one of our studies could not match the results between pretest-posttest because the platform used prevented us from doing so. Therefore, we had to apply independent group techniques in order to present the results.

7.4. Outlook

The tools we have developed allow us to see the strengths and weaknesses of educational strategies, for example, that although knowledge about CC is essential, it needs to be accompanied by abilities and attitudes to be more efficient. For example, more studies on the use of attitudes as a moderating variable are needed. In addition, the present thesis only used PSTs and ISTs for the C3-Q test. Therefore, it is necessary to give continuity to the project by creating and designing more instruments aimed at students, parents and the general population. More studies applied to other populations are also recommended in order to be able to contrast our results. In addition, the use of a control group design is required to support more robust results. Regarding the scale design, it is recommended that these have categories higher than four for better reliability results.

Overall, despite our promising results, replication of our results is encouraged to deepen our understanding of the functioning of C3 and its improvement through training courses such as MOOCs. This will provide further support for our results. In addition, the creation of learning strategies such as those developed in this thesis and their good results is just a sample of the incredible power of education as a tool to confront CC.

As for future lines of research, it is encouraged to continue to do so with topics related to those present in this thesis project. To the extent that we can propose efficient ways to develop C3 we can mobilize society.

Chapter VIII

References and appendices

8. Chapter VIII. References and appendices

8.1. References

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8.2. References developed during the thesis project

Work carried out in this Ph.D. Thesis has resulted in the following achieves:

Book chapters

- Ruiz, C., & **Ferrari, E.** (2019). Capítulo XI. El rol de la educación como herramienta fundamental para movilizar a la sociedad frente al problema del cambio climático. In R. Fernández-Reyes & D. Rodrigo-Cano (Eds.), *La comunicación de la mitigación ante la emergencia climática* (pp. 247–268). Egregius.

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- Ballegeer, A.-M., Fuertes, M. A., Andrés, S., Corrochano, D., Delgado, L., Herrero-Teijón, P., **Ferrari-Lagos, E.**, Asensio, M. I., Flores, J. A., Rodríguez, F., Barbosa, A., Alvarez, R. F., Valladares, F., Lagüela, S., Martínez, J., Alonso, M. L., Rodríguez, E., Heras, F., Gatta, D. F. D., … Vega, J. A. (2019). The university facing the challenges of climate change: A virtual seminar for climate change education. In ACM (Ed.), *ACM International Conference Proceeding Series*. ACM. https://doi.org/10.1145/3362789.3362838

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- **Ferrari-Lagos, E**., Martínez-Abad, F., & Ruíz, C. (2020). The importance of motivation and communication in MOOCs as elements to increase completion rates: A study at MOOCs on Climate Change. In ACM (Ed.), *ACM International Conference Proceeding Series* (pp. 1042–1047). ACM. https://doi.org/10.1145/3434780.3436633

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Papers

- **Ferrari, E**., Ballegeer, A.-M., Fuertes, M. A., Herrero, P., Delgado, L., Corrochano, D., Andrés-Sánchez, S., Bisquert, K. M., Garcia-Vinuesa, A., Meira, P., Martinez, F., & Ruiz, C. (2019). Improvement on social representation of climate change through a knowledge-based MOOC in Spanish. *Sustainability (Switzerland)*, *11*(22). https://doi.org/10.3390/su11226317

- Miguel Ángel, Fuertes, Santiago, A., Corrochano, D., Delgado, L., Herrero-Teijón, Pablo Ballegeer, Anne Marie **Ferrari-Lagos, E.**, Fernández, R., & Ruiz, C. (2020). Climate Change Education: A proposal of a Category-Based Tool for Curriculum Analysis to Achieve the Climate Competence. *Education in the Knowledge Society*, *21*, 1–13. https://revistas.usal.es/index.php/eks/article/view/22823

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Special Issues

- The Climate Competence in Education.
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- Interactions between Climate Science and Education.
  https://www.mdpi.com/si/65896