Climate Change Education and Literacy at the Faculty of Physical and Mathematical Sciences of the University of Chile

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Climate Change Education and Literacy at the Faculty of Physical and Mathematical Sciences of the University of Chile

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Abstract: Considering the role that Higher Education Institutions (HEIs) play in terms of catalysing change within societies, over the past years, sustainability initiatives within HEIs have flourished worldwide. Likewise, the scientific evidence of anthropogenic Climate Change has been on the political and academic agenda for decades, thus the importance of ameliorating Climate Change Education and Literacy both at the society and university training levels. Accordingly, certain questions arise: What are the most effective current Climate Change educational methodologies? Which road map would be the most appropriate to be suggested to HEIs to promote Climate Change Literacy within society and future professionals? In order to begin addressing these questions, the Faculty of Mathematical and Physical Sciences of the University of Chile (FCFM) approach in Climate Change Teaching and Literacy is characterised. The later contemplates the history of the institutionalisation of sustainability at the FCFM, collection of courses and Minors for students which incorporate Climate Change related-topics, as well as Climate Change related research centres.
Keywords: climate change, global warming, education, literacy, teaching, engineering, sciences.

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Claudia Mac-Lean obtained the Industrial Engineer diploma (2010) from the University of Chile. She completed the MPhil in Engineering for Sustainable Development degree at the University of Cambridge in 2012. Since 2013 she works at the Faculty of Physical and Mathematical Sciences of the University of Chile, implementing and developing the Office of Engineering for Sustainable Development. Her research mainly focuses on education in engineering for sustainable development.

Juan Morales is a fifth year geology student at the Faculty of Physical and Mathematical Sciences of the University of Chile. He has undertaken three of the four courses focused on Climate Change at the Faculty.

Andrés Monares is an anthropologist and adjunct professor in the Humanities Area at the Engineering Faculty of Universidad de Chile. He develops research and teaching about the basics of philosophical and cultural systems of the modern era and its impact on Latin America. On these subjects he has published the books Reformation and Enlightenment (2012) and Theologians who built Modernity (2012).

1. Introduction

Anthropogenic Climate Change constitutes the most pressing global issue of the 21st Century. Emissions of Greenhouse Gases since the beginning of the industrial revolution have accumulated in the atmosphere. These affect the energy balance of the earth, enhancing the natural atmospheric greenhouse effect, producing what we call anthropogenic climate change (IPCC, AR5, 2014).

The level of emissions already emitted and those to come imply that civilization will need both to adapt to and mitigate Climate Change. Addressing both aspects of Climate Change requires professionals that understand the physical system, the adaptation needs, and can imagine and propose the mitigation options for a sustainable future of the Earth. Engineers and scientists, have therefor an important role to play in the global Climate Change issue. Hence the importance and urgency of including these subjects in the undergraduate and graduate degrees curricula in an engineering school.

Education is a fundamental component for accomplishing sustainable development. Accordingly, the United Nations General Assembly proclaimed the UN Decade of Education for Sustainable Development in December 2002 (DESD-United Nations, 2005-2014). Universities assume a key role in advancing, promoting and developing the idea of sustainability through numerous ways. For
example through new educational programs and methodologies, collaborative research, cooperation with private and public entities, and Campus initiatives. Indeed, since 1990 education for sustainable development has been on the programs of various engineering faculties (Segalas et al., 2010), and much progress has been made throughout the most recent decade in developing different approaches to introduce the concepts and challenges related with sustainable development to engineering students (Fenner, 2013).

The process that lead towards institutionalising sustainability at the Faculty of Physical and Mathematical Sciences (FCFM) of the University of Chile plays a central role in the ability of addressing Climate Change Literacy, and is hence subsequently described.

The history of the Sustainable Campus (SC) initiative at the FCFM of the University of Chile, can be divided into three periods, each of one marked by the appearance of a new player dedicated to sustainability within the Faculty:

- Student group Oikos (2005),
- Sustainable Campus Commission (2011), and

The first initiative arises from a group of students, Oikos, who originally became organised with the idea of promoting recycling on Campus. These students also noticed other problems related to the environment that needed a broader framework, thus they adopted and embraced the Sustainable Campus concept.

A Sustainable Campus should seek environmental, social and economic sustainability; it should be built in a democratic and participatory manner – including students, academic and administrative staff, and cover all aspects of University tasks: teaching, research, operations and outreach.

After five years of work, Oikos realised that a change of strategy was needed. Campus sustainability could not remain the responsibility of a group of students; it was up to the Faculty as a whole to take on this challenge. The group, along with two academics, submitted a proposal to the Faculty Council to create a Sustainable Campus Commission in 2010. The proposal was accepted, and as a result the Sustainable Campus Commission was created in 2011, whose main goal was to advise the Dean in sustainability matters. The Commission was composed of students, academics, and administrative staff.

Between 2011 and 2013, the Commission implemented projects related to academia, outreach and resource management. Relevant activities that took place during this period of time include the drafting of the Sustainable Campus Plan for the FCFM and the participation in the drafting of the Sustainability Policy for the University of Chile (2012). One of the most important conclusions reached at this stage, was the necessity of hiring a full-time sustainability expert to carry out the Sustainable Campus project.

Consequently, the FCFM authorities created the position of Sustainability Chief and the Office of Engineering for Sustainable Development, which marks a milestone in the institutionalisation of the Sustainable Campus challenge at the FCFM. The expert on the subject would be responsible for supporting the management and development of all initiatives carried out both inside and outside the Faculty.
Thus, in March 2014, the Office of Engineering for Sustainable Development was established. This area seeks to promote and integrate a culture of engineering for sustainable development at the Faculty, as an enhancing element of the formation of the students. In order to achieve this, the Office works in four aspects: teaching, research, operations and organisation of the Campus, and outreach.

The Office of Engineering for Sustainable Development is currently working in the incorporation of sustainability-related skills and competences in the profile of the engineering graduates that would allow them to:

- Create a link between sustainable development and complex systems analysis, in its social, environmental and economic dimensions,
- Assume sustainability as an attribute of their responsible professional and personal development,
- Integrate sustainability methodologies and systemic thinking in their own discipline, and
- Discuss, conceive, and propose sustainable solutions in their working environment, community and country.

Additionally, the Office of Engineering for Sustainable Development is dedicated to the compliance of a Cleaner Production Agreement signed with the Chilean Government. This commitment contemplates the identification and characterisation of sustainability-related courses and research, information that was fundamental in the process of assessing Climate Change Literacy at the Faculty.

In summary, there has been a successful history of sustainability incorporation and institutionalisation at the Faculty of Physical and Mathematical Sciences of the University of Chile, integrating both bottom-up and top-down approaches.

2. Climate Change teaching and research at the FCFM

In order to evaluate the level of Climate Change Literacy at the FCFM, it would be recommendable first to explore and assess the level of knowledge students have of the subject, by identifying the Climate Change offer in the curricula and outreach activities of the Faculty.

With the aim of characterising the academic offer, an effort was made to list the courses, Minors, and research centres – both focused and related in Climate Change. To contextualise, the FCFM is composed by thirteen Departments: nine engineering specialities and the Geology, Physics, Astronomy and Geophysics Department. The total number of undergraduate students is around 4,800, of which approximately a 20% are women.

2.1 Climate Change related courses

Beginning in the years 2009 and 2010, an increasingly number of courses that address the issue of anthropogenic Climate Change emerged in the undergraduate level at FCFM, both in a compulsory and elective scheme. The entire academic staff of around 220 full-time professors was contacted through mailing lists, in order to begin identifying the courses that included Climate Change – as
solely the sustainability-related courses catalogue was available by then. A summary of the courses that address Climate Change at any level of depth is given in Table 1. It is worth mentioning that this list corresponds to the first approximation of course offered at the FCFM, but might not be exhaustive. The currently available full list of courses is given as supplementary material.

<table>
<thead>
<tr>
<th>Course Characterisation</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course by Department</td>
<td>6 DIC</td>
</tr>
<tr>
<td></td>
<td>4 Workshops</td>
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<tr>
<td></td>
<td>4 Other Departments</td>
</tr>
<tr>
<td></td>
<td>3 IQBT</td>
</tr>
<tr>
<td></td>
<td>2 DGF</td>
</tr>
<tr>
<td>Level of Depth</td>
<td>4 courses with full dedication</td>
</tr>
<tr>
<td></td>
<td>4 courses with a unit</td>
</tr>
<tr>
<td></td>
<td>10 courses with an individual class</td>
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<tr>
<td></td>
<td>5 courses with exercises/homework</td>
</tr>
<tr>
<td>Course Type</td>
<td>9 compulsory</td>
</tr>
<tr>
<td></td>
<td>11 electives</td>
</tr>
<tr>
<td>Semester</td>
<td>3 in 3rd semester</td>
</tr>
<tr>
<td></td>
<td>5 in 5th or 6th semester</td>
</tr>
<tr>
<td></td>
<td>11 no defined semester</td>
</tr>
<tr>
<td>Topics Covered</td>
<td>All aspects of Climate Change: Physics Basis, Impacts and Mitigation</td>
</tr>
<tr>
<td>Teaching Methodology</td>
<td>9 courses utilise lectures</td>
</tr>
<tr>
<td></td>
<td>13 courses utilise group work and discussion</td>
</tr>
<tr>
<td>Evaluation Methodology</td>
<td>Project, Exam, Reports, and Presentations</td>
</tr>
<tr>
<td>Average Number of Students</td>
<td>2 courses &gt;= 60 students</td>
</tr>
<tr>
<td></td>
<td>3 courses = 40 students</td>
</tr>
<tr>
<td></td>
<td>15 courses = 10-20 students</td>
</tr>
</tbody>
</table>

Table 1: Summary of courses at FCFM that address Climate Change. Acronyms of departments: DGF: Department of Geophysics, DIC: Department of Civil Engineering, DIE: Department of Electrical Engineering, DIMEC: Department of Mechanical Engineering, DMIN: Department of Mining Engineering, EH: Humanities Studies, EI: Engineering School, IQBT: Department of Chemistry and Biotechnology.

Twenty courses where identified to cover the topic of Climate Change at the FCFM, of which four courses have complete dedication to Climate Change, four courses include a unit, ten courses cover the topic in a single class, and five incorporate it with an exercise or homework. Nine of these courses are compulsory – out of a universe of about 240 compulsory courses at the FCFM, and eleven are offered in an elective scheme. The majority of these courses are therefore taken by students between their 3rd and 6th year of study, as only the workshop compulsory courses are given in the Common Core – initial two years core programme in mathematics, physics and computer science.

The twenty courses cover all topics related to Climate Change, from the physical basis to impacts and mitigation. These topics encompass the seven essential principles of climate science and Climate Change Literacy as defined by United States Global Change Research Program (Climate Literacy, 2009). It is therefore possible to conclude that the courses meet the content standards set by the Climate Change Literacy principles. It is interesting to note that most courses contemplate group work and discussion as a teaching methodology in this subject (13 courses), together with the conventional lectures, and hence encourage active learning methodologies. A final variable of interest in the characterisation of the courses has been the number of students that undertake them.
Most courses (15) have between 10-20 students, and only two courses have more than 60 students. Six different departments provide the courses, most significantly the Departments of Geophysics, Civil Engineering, and Chemistry and Biotechnology; plus a few workshop courses dictated during the two first common years.

In summary, it has been found that the number of courses which address – to different extent – the Climate Change subject is still comparatively reduced within the FCFM undergraduate curricula, even at the level of individual classes or units. As it has already been mentioned, there is no certainty that the identified courses represent the full set of courses offered. It is also worth mentioning that in the process of gathering this information, a number of professors commented that they would be interested in including this topic in their courses, indicated thus a potential in increasing the Climate Change topic in the Faculty curricula.

2.2 Climate Change focused courses

From the list of recognised courses to cover Climate Change at the FCFM in the previous section, those that are entirely dedicated to Climate Change as their main topic, are here described. A brief description of the courses, their learning outcomes, and teaching and evaluation methodologies are presented.

- **Workshop Project: Climate Modelling**

_**Description:**_ The Workshop Project is an obligatory course for 3rd semester engineering students at the FCFM, and this is one of the approximately 35 sections offered, dictated by the Department of Geophysics. The aim of the course is to give the student an early experience of developing a research project in the specific realm of climate modelling. The course is arranged for 14 or 16 students, working in pairs.

Throughout the semester students use a real climate model to run experiments in order to test some hypothesis about the functioning of the climate system. Students have no previous knowledge of atmospheric physics, Linux operating system, and various software used to analyse the experiments that they produce. It is therefore a challenging course on many levels. However, the proper understanding of anthropogenic Climate Change requires system thinking that can be developed by using a complex climate model.

_**Learning Outcomes:**_ At the end of the course, the student conceives, designs, implements and operates a numerical experiment with a computer model of the climate system to evaluate a hypothesis of how the climate system works, and has reflected on the effects of human activities on the planet.

_**Teaching Methodologies:**_ This is a hands-on course in a computer laboratory where students design, carry out and analyse a number of climate simulations. Teacher and teaching assistant are there during the class to answer questions and give advice. The first class only is a lecture given by the professor. Afterward, each group carries out two simulations, the common control and the experiments – where they change a boundary or initial condition.

During the last third of the course the groups are asked to analyse one aspect of the simulations and at least two experiments. In this manner, social learning is enabled within the students, and
comparative analysis of the effects of different forcings on a particular aspect, such as temperature, precipitation or the winds for example, can be made.

**Evaluation Methodologies:** The evaluation is carried out by 3 written reports, and a final oral presentation. The aim of the opening report is to inform on the analysis of the control simulation, which is common to all groups, and thus students learn about the main characteristics of present day climate. The second report informs about the experiment carried out by each group and the comparative analysis of changes introduced by the experiment. Finally, the third report informs about the analysis of a given aspect of the climate system response in more than one experiment. Both in the second and third report, students are asked to include a reflection on anthropogenic Climate Change in the light of their experiments. The final exam corresponds to the oral presentation of the third report.

- **Introduction to Meteorology and Oceanography**

**Description:** The purpose of this course is to provide students with the basic tools of meteorology and atmospheric sciences, to understand the processes occurring in the atmosphere and its role in the climate system. To this aim, analysis of instrumental data on-site or remote and atmospheric models are made, differential and integral equations are solved in simple problems, interpreting the results qualitatively and quantitatively, and qualitatively describe meteorological fields.

**Contents and Learning Results:** The course content is divided into five modules: I. Basic properties of the atmosphere and climate system; II. Radiative transfer: this includes energy balance and the greenhouse effect; III. Thermodynamics, clouds and precipitation; IV. Atmospheric dynamics; V. Mid-latitude weather systems. One of the expected learning outcomes is to distinguish natural climate variability and anthropogenic climate change.

**Teaching Methodologies:** Active-participatory classes. Laboratory and homework.

**Evaluation Methodologies:** Three mid-term tests and a final written examination. The grading also comprises laboratory reports and homework.

- **Climate System**

**Description:** The purpose of this course is students to understand the functioning of planet Earth, along its entire evolution in relation to the Earth's climate. This includes: planets formation, conditions for life, climate variability at different time scales, and ongoing Climate Change. There is a particular emphasis made during classes on a critical analysis of the material provided.

**Contents and Learning Outcomes:** The course is divided into four main modules: I. Climate System Fundamentals, II. Long term Climate Change (geological timescales), III. Orbital scale Climate Change, and IV. Present and Future Climate Change.

At the end of the course, students are expected to analyse the processes that control the dynamics of the Earth system along its entire evolution, using computational climate models, in order to make a critical analysis of the effect of human and natural forcings of the Earth system. Students are also able to communicate in writing and orally the results of a research project that addresses one aspect of the functioning of the climate system chosen by the student, properly using technical language.
Teaching Methodologies: The contents and learning outcomes of the course are delivered through the following activities:

- Lectures where the fundamental theoretical aspects will be addressed,
- Analysis of relevant literature (in English) through reflective reading and group discussion,
- Computer labs to instruct on the use of simple climate models,
- A research project, and
- Discussion of audio-visual material related to the course content.

Evaluation Methodologies: The evaluation methodologies used in this course are: Written exams, Homework, tests assessing article reading, Lab reports, and the evaluation of the research project through written and oral reports.

- Global Environment and Climate Change: Socio-cultural, political, and economic perspectives.

Description: This course addresses the crisis of the global Climate Change, as a natural, historical and cultural phenomenon, which incorporates the modern Western life-style and non-human aspects. The course firstly reviews a basic understanding of the climate system and the physical evidence of global warming. Then, the ideological foundations of modern thinking which have led to the current western specific type of relationship between humans and non-human elements in nature are presented. Finally, the course closes with an open forum for discussion of possible alternative scenarios to tackle global Climate Change.

Contents and Learning Outcomes: The contents of the course are divided into three modules: I. Climate Change: physical aspects. This includes an introduction to the climate system and Climate Change on Earth, greenhouse gases effect and energy balance, and its relation with human activities; II. Fundaments of the relationship between humankind and nature in the western world; III. Climate Change, society, politics, and environmental conflicts.

Teaching Methodologies: The course blends traditional expository classes together with group work, in which students discuss given readings. Audio-visual material (documentary) is also used to stimulate critical thinking and discussion. Finally, a lectures series is given by experts and practitioners.

Evaluation Methodologies: The learning outcomes of this course are assessed through two three written exams, as well as grading of group discussions.

2.3 Climate Change related Minors

The Faculty of Physical and Mathematical Sciences of the University of Chile offers 28 Minors. Each Minor has a defined study programme and course requirements. It is worth mentioning that students also have the possibility to alternatively take five elective courses to their own election.

In the present section the Minors related to Climate Change are described, by exhibiting their learning outcomes and study programme.
Minor in Meteorology and Climate

Learning Outcomes: Identify and describe the essential components of the climate system which are relevant for the civil engineering, geology and geophysics specialities; Examine the climate system forcing effects, distinguishing the natural and anthropogenic forcings; Identify and describe the physical and chemical processes of relevance to air pollution problems; Use data collection methodologies and develop meteorological information analysis, in applied problems.

Study Programme: The Minor in Meteorology and Climate is composed of the following courses: Climate System, Atmospheric Pollution, Applied Meteorology, and Atmospheric Fluid Dynamics.

Minor in Renewable Energies

Learning Outcomes: The student is expected to be able to understand the basic principles of power generation from renewable sources. Furthermore, he/she will be able to identify the generation potential of specific locations and sources, such as geothermal reservoirs, wind power, solar radiation, and hydro power.

Study Programme: This Minor’s structure corresponds to the following five compulsory courses: Electricity Generation from Renewable Sources, Introduction to Meteorology and Oceanography, Geothermal Principles, Introduction and Application of Solar Energy, and Renewable Energy from Biomass.

Minor in Engineering for Sustainable Development

Learning Outcomes: Students are expected to engage with sustainable development, addressing the institutional commitment of forming professionals who embrace environmental and social responsibility. Accordingly, students are expected to acknowledge methodological tools to incorporate sustainability in engineering projects.

Study Programme: This Minor is composed of mandatory and elective courses. The mandatory courses are: Introduction to Sustainability in Engineering and Sustainability Workshop. The three elective courses are selected by the students from a list of around 15 sustainability courses offered at the FCFM. These courses include subjects such as climate systems, sustainability in construction, innovation for sustainability, sustainability in mining engineering, social project evaluation, and renewable energies.

2.4 Climate Change and Research Centres at the FCFM

The FCFM leads several research centres. One of them focuses directly on Climate Change – the Centre for Climate and Resilience Research, while others are related to Climate Change as their research focuses on energy generation and renewable energies. The purpose and/or research emphasis of each of those centres are subsequently briefly described.

Centre for Climate and Resilience Research
This centre’s research focus is on Earth System Science, with an interdisciplinary approach and in close relation to stakeholders, in order to contribute to a better understanding of the Earth System and also to societal resilience in Chile.

**Centre of Energy**

This centre aims to contribute to the energy sector by developing and introducing innovative technological solutions, which are relevant for national development and internationally competitive. Their research develops around three key areas: Smart grids and distributed generation, electric vehicles and accumulation systems, and the development of tools to support decision-making.

**Chilean Solar Energy Research Centre**

The objective of the centre is being a world leader in scientific research on solar energy, with special emphasis on developing the potential of the Atacama Desert in Chile.

**Andes Geothermal Centre of Excellence**

This centre seeks to generate the necessary scientific knowledge to turn geothermal energy into a sustainable, environmentally friendly and economically competitive source. With the purpose of increasing geothermal energy generation within the energy matrix of Chile and the Andean countries.

In this initial characterisation of Climate Change research activities at the FCFM, a significant relationship to undergraduate teaching or outreach was not found. Probably the teaching target of these centres is at the graduate degrees. However, this apparent lack of relationship with the large number of undergraduate students reflects either no clear communication mechanisms or effectively little development of such ties.

### 3 Climate Change students’ literacy at the FCFM

An online survey was conducted in order to gather information about Climate Change Literacy and sustainability among students at the FCFM. The survey focused on three areas: knowledge, skills and attitudes about Climate Change and sustainability. This instrument was based on the survey "Americans' Knowledge of Climate Change 2010", prepared by the Yale Project on Climate Change Communication (Leiserowitz et al, 2010). The complete survey included 24 questions from Leiserowitz et al, (2010) in addition to four more that where needed. The full list of 29 questions is given as supplementary information.

#### 3.1 Characterization of respondents

The survey reached a total of n=169 undergraduate students, covering the Common Core and the 13 specialties offered at the FCFM.

The respondents’ distribution is similar to the FCFM one, with an over-representation of the Mechanical, and Chemistry and Biotechnology Engineering Departments, and an under-representation of the Computer Engineering Department. In terms of gender composition, the
respondents’ sample is composed in 31% by female students, which is ten points higher than the 21% percentage of women students at the Faculty. Table 2 gives the summary number of respondents by Department and semester.

<table>
<thead>
<tr>
<th>Specialty</th>
<th>Nº of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Core</td>
<td>37</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>23</td>
</tr>
<tr>
<td>Geology</td>
<td>18</td>
</tr>
<tr>
<td>Industrial Engineering</td>
<td>17</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
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</tr>
<tr>
<td>Electrical Engineering</td>
<td>14</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>14</td>
</tr>
<tr>
<td>Mining Engineering</td>
<td>10</td>
</tr>
<tr>
<td>Mathematical Engineering</td>
<td>6</td>
</tr>
<tr>
<td>Astronomy</td>
<td>4</td>
</tr>
<tr>
<td>Geophysics</td>
<td>4</td>
</tr>
<tr>
<td>Physics</td>
<td>2</td>
</tr>
<tr>
<td>Biotechnology Engineering</td>
<td>2</td>
</tr>
<tr>
<td>Computer Sciences</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specialty</th>
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<td>1st</td>
<td>2</td>
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<tr>
<td>2nd</td>
<td>2</td>
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<td>3rd</td>
<td>25</td>
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<td>4th</td>
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<td>5th</td>
<td>30</td>
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<td>7th</td>
<td>31</td>
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<td>10th</td>
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<td>11th</td>
<td>8</td>
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<tr>
<td>12th</td>
<td>10</td>
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<tr>
<td>13th and more</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 2: Characterisation of respondents by department and semester.

For the analysis of the survey the respondents were segmented according to the courses they have undertaken at the Faculty:

1. Those who declared have taken at least one course focused on Climate Change ("CC");
2. Those who declared have taken at least one course focused on sustainability ("Sust");
3. Those who declared have taken at least one course in each area: Climate Change and sustainability ("Both");
4. Those who have declared not attending any course on Climate Change nor sustainability ("Neither").

The number of students falling into each of the four segments is presented in Table 3. The total number of respondents n=169 is given by the sum of the segments "CC", "Sust", and "Neither", minus "Both" since it corresponds to the intersection between "CC" and "Sust". A clear tendency for students that have taken Climate Change and/or sustainability courses in giving their time and engaging to respond to this survey can be observed in Table 3.

<table>
<thead>
<tr>
<th>Segment of students</th>
<th>Nº of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>65</td>
</tr>
<tr>
<td>Sust.</td>
<td>78</td>
</tr>
<tr>
<td>Both</td>
<td>40</td>
</tr>
<tr>
<td>Neither</td>
<td>66</td>
</tr>
</tbody>
</table>

Table 3: Characterisation of respondents according to courses undertaken.
In order to more directly assess the impact of expected learning outcomes acquired in the courses, only results for the extremes "Both" and "Neither" are shown. The survey results are subsequently provided, in view of the three dimensions – knowledge, skills, and attitudes and concern.

**Knowledge.** From the 29 questions that composed the survey, 18 correspond to Climate Change “knowledge” questions (questions N° 2-4 and N° 6-20). To set answers as correct or incorrect, in questions that have options like very, somewhat, probably true; for simplicity of analysis, alternatives were regrouped as "Yes", "No" and "I Don’t know". Figure 1 shows the average answers for the two extreme segment of respondents.

![Figure 1: Results of knowledge questions. Left: students that have taken Climate Change and sustainability courses. Right: students that have neither taken Climate Change nor sustainability courses.](image)

Figure 1 exposes that there is consistency between the number of Climate Change and sustainability courses taken and the level of knowledge about the field of interest, with 67% of right answers versus 58% of right answers. Likewise, the analysis of the full four initially defined segments also shows a clear increasing level of correct answered questions that comes along with increasing Climate Change and sustainability courses undertaken.

Questions N° 21 and N° 23 refer to the source of information. Figure 2 shows that 19% of the respondents that have taken both Climate Change and sustainability courses at the FCFM, affirm that their main source of information was provided by the Faculty, versus 7% in students who have not done it.
Skills. The self-evaluated skills in Climate Change knowledge was assessed in two questions: N° 22 “In order to have a solid opinion about global warming;” (Figure 3), and question N° 24 “Do you think you manage knowledge and practices that would allow you to properly address the problem of Climate Change in your personal life and professional future?” (Figure 4).

As it also occurred with the Climate Change knowledge questions, there is a clear tendency in self-evaluated skills and number of courses taken. A significant decrease in the need for “a lot more information”, in respondents who have taken both Climate Change and sustainability courses at the Faculty, is observed.
Figure 4 exposes question Nº 24 results, and again, students that have taken more Climate Change courses are more secure about their capabilities to address this issue in their personal and professional life.

**Attitudes and Concern.** The attitude and level of concern towards Climate Change was addressed in two questions: question Nº 1: "How much had you thought about global warming before answering this survey? And question Nº 5: "How worried are you about global warming? The results are shown in Figure 5. A positive relationship between the number of courses taken and the level of concern is found, more significantly in the “Very concerned” increase of responses.
4 Conclusions and future steps

This paper reports on the first attempt to characterise Climate Change Education and Literacy at the Faculty of Physical and Mathematical Sciences of the University of Chile. Towards this goal, we collected a list of courses, and their methodological characteristics, that are related or focused on Climate Change at the Faculty. Secondly, a student survey was conducted with the purpose of evaluating students’ knowledge, skills, and attitudes and concern.

In terms of methodological approaches, it is interesting to note that active methods are commonly used in Climate Change courses at the FCFM. Group work and discussion, project-based learning, social learning, self-reflecting reports, and critical thinking, are reported as being currently utilised as teaching and evaluation methodologies. Whereas the traditional approach of lectures and exams are typically dominant within the FCFM.

As it has already been mentioned, this is the first attempt to identify Climate Change courses at the FCFM, so the list of courses might not be exhaustive. Six departments provide the courses, most significantly the Departments of Geophysics, Civil Engineering, and Chemistry and Biotechnology; plus a few workshop courses dictated during the two first common years. A proxy for the scope of Climate Change curricula presence at the FCFM could be the percentage of compulsory courses, which include the topic: 3.7%. This number should be increased, especially in the Common Core, and in the more numerous Departments of Industrial and Electrical Engineering.

Likewise, during work in progress the authors received a number of comments from professors interested in including the Climate Change topic in their courses, hence there is a clear potential of increasing the presence of Climate Change in the curricula. For example, one can easily visualise that most of the sustainability related and focused courses, could also address Climate Change, and hence reach a greater number of undergraduate students at the FCFM. Expanding the Climate Change curricula offer could be facilitated by organising a series of Climate Change and sustainability classes, specifically designed for FCFM professors. The expected outcome of the classes should be the exercise, lecture, and/or unit to be incorporated by the assisting professors into their own courses. A strategy to further increase Climate Change in the FCFM curricula should follow the guide of “Climate Literacy: The Essential Principals of Climate Sciences”, developed by the United States Global Change Research Program.

Regarding Climate Change research at the FCFM, no significant relationship of the centres with neither undergraduate teaching nor outreach was found. Probably because the teaching target of these centres is at the graduate level. However, this apparent lack of relationship with the large number of undergraduate students shows either no clear communication mechanisms or effectively little development of such ties. Hence, there seems to be an important potential of increasing Climate Change education and literacy through these research centres at the FCFM.

Also regarding research, at least the Centre for Climate and Resilience Research explicitly declares an interdisciplinary and stakeholder approach, which is fundamental in tackling the global Climate Change issue. Similar to what was found in Climate Change teaching, necessary and uncommon practices are found in the Climate Change research realm. Therefore further incorporating Climate Change into the curricula and research at the FCFM, will also contribute to the transformation process towards the incorporation of sustainability related competences and skills in our engineering graduates.
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With respect to the students’ survey, it was possible to diagnose a significant positive impact of the existing Climate Change curricula in the students’ knowledge, skills, and attitudes and concerns. It was also found that a general interest in this topic exists among the student community that has been less exposed to Climate Change topics in their curricula.

It can therefore be concluded that there is a fertile ground for deepening Climate Change Literacy, from both sides: the curricula offer and students interest, at the FCFM. To our knowledge this corresponds to the first assessment of Climate Change education and literacy in Chile.

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References


